AQUACULTURE DEVELOPMENT IN SOUTHEAST ASIA AND JAPAN AND PROSPECTS FOR SEAFARMING AND SEARANCHING

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Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia and Prospects for Seafarming and Searanching

19-23 August 1991
Iloilo City, Philippines

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Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia and Prospects for Seafarming and Searanching
19-23 August 1991; Iloilo City, Philippines

ISBN 971-8511-27-X

Published by
Aquaculture Department
Southeast Asian Fisheries Development Center (SEAFDEC)
Tigbauan, Iloilo, Philippines

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AND PROSPECTS FOR SEAFARMING AND SEARANCHING

Contents

FOREWORD

Aquaculture is necessary to produce more fish in the face of decreasing supply from marine fisheries and increasing demand from the burgeoning population. The challenge is how to make the best possible use of coastal and inland waters for aquaculture at low levels of costly inputs and without adverse environmental and socioeconomic changes.

Since its establishment more than 20 years ago, the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD) has generated technologies that contributed significantly to the development of aquaculture in the region. Aquaculture technologies must of course keep abreast with the present and future needs and challenges of the industry. Thus the first Seminar on Aquaculture Development in Southeast Asia (ADSEA '87) assessed aquaculture research and development in the region.

In the past 10-15 years, the aquaculture industry was confronted with many problems, particularly, the environmental and socioeconomic effects of intensive culture. Thus, ADSEA '91 was convened in Iloilo City, on 19-23 August 1991 to review recent developments in aquaculture and to redirect SEAFDEC/AQD's efforts toward environment, friendly and socially equitable aquaculture. Prospects for seafarming and searanching were therefore discussed. The idea is that aquaculture must enhance, not degrade coastal resources, and improve, not take away, the livelihood of small-scale fisherfolk and fish farmers. The technologies developed by SEAFDEC/AQD must contribute to sustainable development of the region's aquatic resources.

ADSEA '91 established a set of priority species for aquaculture and identified problems for further research as well as strategies for seafarming and searanching. These guided the research and development program of SEAFDEC / AQD from 1992 to 1994.

ADSEA '91 would not have been a success without the active participation of the representatives of the participating countries and cooperating agencies, and the efforts of the Workshop Committee members. On behalf of SEAFDEC/AQD, I thank the International Development Research Centre (IDRC) of Canada and the Government of Japan for sponsoring ADSEA '91.

This volume of **ADSEA '91 Proceedings** contains review papers on aquaculture research and development as well as regional and country experiences. Let this be one contribution towards sustainable aquaculture development in Southeast Asia.

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Chief
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18 May 1994

Review of SEAFDEC/AQD Research 1988-1991

In:F Lacanilao, RM Coloso, GF Quinitio (Eds.). Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia and Prospects for Seafarming and Searanching; 19-23 August 1991; Iloilo City, Philippines. SEAFDEC Aquaculture Department, Iloilo, Philippines. 1994. 159 p.

SEA BASS, GROUPERS, AND SNAPPERS

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ABSTRACT

Studies on sea bass (*Lates calcarifer*) broodstock were directed at techniques to maximize egg production. Now known are the: optimum luteinizing hormone releasing hormone analogue (LHRHa) dose range to induce spawning, optimum egg size responsive to LHRHa induction, appropriate time for induction, proper storage conditions for LHRHa, and induction of spermiation in males. Gonadal maturation and spawning are successfully induced by LHRHa and/or 17 alpha-methyltestosterone. An experiment on photoperiodic induction of sexual maturation is being conducted to produce seed year round. Increased information on larval morphology and physiology of sea bass led to improvements in feeding strategies and transport techniques. Studies on nutrient requirements and practical diets are currently being undertaken for different stages/sizes of sea bass. An economic assessment found an integrated sea bass production system viable.

Studies on groupers (*Epinephelus* spp.) have been geared towards broodstock development including induction of sex inversion by hormonal control, intraspecific interaction, and sex control using synthetic anabolic steroids. Spontaneous maturation and successive spawnings of captive *Epinephelus suillus* were achieved in 1990. Larval rearing techniques used for other marine fish species were tried but with limited success. Culture techniques in ponds and floating cages using SEAFDEC-formulated diets or commercial pellets are being developed.

Studies on snappers (*Lutjanus* spp.) have been started with the identification of species common in Panay Island.

INTRODUCTION

Fishfarmers are currently searching for alternative high-value aquaculture species following the decline of the export market value of shrimp. The popularity and high market demand of tropical sea bass, groupers, and snappers make them obvious choices for culture. However, culture of these species is constrained by insufficient seed supply, high production costs, and lack of cost-effective feeds.

Cognizant of the need to eliminate these constraints, the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD) conducted research in the following general areas: 1) sea bass breeding, larval rearing, grow-out culture, nutrition, and farm socioeconomics, (2) grouper species identification, breeding, larval rearing, grow-out culture, and disease control, 3) snapper species identification and market survey.

This paper reviews the results of studies conducted at SEAFDEC/ AQD over the past four years. However, many of these results are yet to be published.

SEA BASS

Breeding

Sequential and multiple spawnings of sea bass were first achieved by injection, pellet implantation, or by osmotic-pump implant of mammalian and salmon gonadotropin hormone-releasing hormone analogue (GnRHa) (Almendras et al. 1988). Pellet implantation is most effective. Stimulation of multiple spawnings is almost similar if mammalian or salmon GnRHa is used or if the stimulation is applied at the first quarter or new moon phase.

Hormone-induced sequential spawning is dose-related. Pelleted luteinizing hormone-releasing hormone analogue (LHRHa) is optimum at doses of 38-75 microgram per kilogram body weight of fish (Garcia 1989a). Mean egg production is highest on the first day and gradually declines on subsequent days. Despite the advantages of pellet implantation, injection is still the most convenient and popular mode of LHRHa administration. The median effective dose of injected LHRHa is about 25 μg/kg among mature female sea bass having a minimum egg diameter of 0.40 millimeter (Garcia 1989b). Fish spawn 30-36 hours after a single injection. An ovarian biopsy technique developed for grey mullet can also be used to determine the stage of ovarian maturity in sea bass (Garcia 1989c).

Sea bass usually spawns in the evening (Garcia 1988). If 20 μg/kg LHRHa is injected at 1100 H or 1700 H, sea bass spawns at dawn. However, those given a single injection at 2300 H or 0500 H spawn at daytime (Garcia 1990b). Unlike spawnings at daytime, spawning at dawn of LHRHa-injected fish results in more eggs. Administration of LHRHa at certain times of the day could provide a convenient means of timing the onset of spawning of mature female sea bass so that a maximum number of eggs may be collected.

Gonadal maturation and spawning can be advanced two months before the peak of the breeding season by long term exposure to pelleted LHRHa or 17 alpha-methyltestosterone (MT) (Garcia 1990a). A single implant in March of 200 μg/kg LHRHa alone or in combination with 20 μg/kg MT induces greater percentage of ovarian maturation (43-71%) 45 days after administration compared to the control group. A lower dose (100 μg/kg) of these hormones also stimulates ovarian maturation (78-80%) in May following three previous monthly implantations. Two to three monthly implantations of LHRHa alone or in combination with MT or MT alone likewise induces testicular maturation in April (90%) and May (100%). Lower rate of maturation (83%) is exhibited by the control group from April to June.

Males mature earlier than females during the spawning season. Hence, milt consistency becomes a problem in the latter part of the season leading to low fertilization and hatching rates. Injection of 20-80 μg/kg LHRHa or 100 μg/kg MT enhances milt production and induces thinning of milt and spontaneous milt release in captive sea bass at the beginning and peak of the breeding season (Garcia 1992). The fertilization rate of hormone-induced sea bass varies and declines towards the end of the breeding season.

LHRHa is now routinely used to spawn mature sea bass broodstock at SEAFDEC/AQD. Unlike a pelleted hormone preparation, solubilized LHRHa diminishes in biological potency after storage for more than 90 days in a refrigerator (4-10°C) or 30 days at room temperature (28-30°C) (Garcia, unpublished results). In these studies, an opercular tag facilitates identification and monitoring of the individual response of fish to hormonal treatments (Garcia and Gapasin 1988).

Nursery

Rotifer consumption of sea bass increases exponentially with growth (Kohno and Duray 1990). Although the mouth width of larvae at initial feeding ranges from 200 to 240 millimeters the larvae ingested rotifers 80-160 mm in size (Duray and Kohno 1990)

Growth and survival of sea bass larvae are promoted when they are fed 6 *Artemia*/ ml/ five times daily starting on the 14th day of rearing (Duray 1990a). High survival is also attained by supplementing *Artemia* with *Moina* (water flea), suggesting the possibility of using *Moina* in rearing sea bass (Fermin 1991). A feeding scheme for sea bass larviculture has now been developed to optimize *Artemia* feeding (Dhert et al. 1990a). Newly hatched *Artemia nauplii* of San Francisco Bay type is offered from Day 8 to 10 and Great Salt Lake *nauplii* from Days 10 to 15 and 24 h enriched *Artemia* instar II thereafter. Feeding highly unsaturated fatty acid (HUFA)-enriched *Artemia* to sea bass larvae (17 mm TL) accelerates the onset of metamorphosis and improves their resistance to salinity stress (Dhert et al. 1990b). "However, fry reared on rice bran-fed pre-adult Artemia grew and survived better than those fry fed partially enriched *Artemia* (Bombeo, personal communication).

Simulated transport studies of sea bass fry at loading densities of 200 and 1600 fry per liter showed similar survival rates after 2-8 hours at 20°C and 20 parts per thousand salinity (Parazo, unpublished results).

Sea bass can be weaned over to an appropriate formulated diet as early as Day 10, but results are not satisfactory (Juario et al. 1991). The best method is to wean larvae gradually starting Day 20. Survival is high and cannibalism is minimized when larvae are reared until Day 60 using this method. Day 21 larvae abruptly weaned over to commercial pellets show lower survival rates (39-49%) compared with Artemia-fed larvae (74%) (Duray 1990b). Studies on the morphological and histochemical development of the digestive tract of sea bass supports the present weaning strategy (Minjoyo 1990). Sea bass juveniles swallow their prey whole and maximum prey size depends on predator mouth width, prey body depth, and total length. The size of prey ingested increases with increasing predator size but not to exceed 60-67% of predator total length (Parazo et al. 1991).

Based on the seed production studies conducted at SEAFDEC/ AQD, a manual on sea bass hatchery operations and results of hatchery runs was published (Parazo et al. 1990, Parazo et al. 1991).

Although sea bass fry are already commercially produced in three private hatcheries in the Philippines, inconsistent survival has been reported. Thus, aside from food and feeding, other parameters like stocking density, light, etc. were investigated. Sea bass larvae survived and grew better when reared under natural lighting conditions than those under continuous light (Duray 1990c). Routine sea bass larviculture used an initial stocking rate of 30 newly-hatched larvae per liter. The stock is reduced halfway every week starting on Day 14. Cannibalism is minimized by culling the "shooters" and transferring them to a separate container (Parazo et al. 1991). In a related study, high growth rates were obtained when fry were stocked in an illuminated cage at 300 fry per cubic meter with or without supplemental feeding; poor growth was obtained at stocking rates of 150 or 600 fry per cubic meter (Fermin, unpublished results). Larvae acclimated to 16, 24, and 32 ppt salinities and subjected to eight test salinities ranging from 0 to 56 ppt showed that Day 23 larvae was most resistant (Javier, unpublished results).

Grow-out Culture

Polyculture of sea bass using tilapia as forage fish is often practiced. Growth and survival were higher among sea bass reared with tilapia in the same compartment than among those reared in ponds with net partition to separate the larger prey from predator (Triño, unpublished). Under laboratory conditions, sea bass actively select tilapia over sibling prey within the first 2 hours of exposure to prey (Avila et al. 1990b). When fed commercial pellets at 1.2 g/kg body weight (BW), the rate of food intake is higher in fishes held in groups than those kept individually. The specific growth rates of sea bass reared on commercial pellets were similar at salinities of 0, 15-16, and 34 ppt (Avila et al. 1990a).

Sea bass grow-out culture is still dependent on trash fish as food. A nutritious cost-effective artificial feed is now being developed to replace trash fish. There are several ongoing studies on the nutritional requirements of sea bass at various life stages. Dietary protein at 43% and dietary lipid at 12% are optimum for growth of sea bass fry (Alava 1990). High survival rates were obtained among juveniles given a high-protein high-energy feed (Catacutan, unpublished results). The quantitative amino acid requirements of sea bass were also studied. Methionine requirement of juveniles was estimated at 2.4% (Coloso, personal communication).

To reduce feed costs, cheaper sources of dietary protein and lipids must be used in formulations. As alternative to fish meal, protein sources such as shrimp head meal, meat and bone meal, soybean meal, and yeasts were evaluated. Sea bass fry and juveniles show better weight gain when fish meal is partially replaced (20%) by shrimp head meal in a 43 or 45% protein diet (Alava 1990). Similarly, cod liver oil, soybean oil, and coconut oil alone or in combination were tried on sea bass fry. Sea bass fed diet with cod liver oil and soybean oil in a 1:1 ratio show higher survival and growth than those fed diet with cod liver oil alone or soybean oil alone (Borlongan and Parazo 1991). Growth and survival are poor in the coconut oil diet and poorest in the diet without lipid supplement. Feed cost can be reduced if fish oil is partially substituted with soybean oil.

Since sea bass is commercially cultured under a wide range of salinities, its physiological response to osmotic stress was studied. Freshwater-adapted fingerlings and sub-adults transferred to seawater are able to regulate plasma osmolality and chloride ion back to normal levels in 2 days (Almendras 1991a). Seawater-adapted fingerlings and sub-adults can do the same in 1 day and 4 days, respectively. Ammonia excretion rate were also studied and found to be higher in freshwater-adapted fry than in seawater-adapted fry (Almendras 1991b). Ammonia excretion rates among freshwater and seawater-adapted sub-adults increased after feeding and returned to pre-feeding level after 10 hours.

Socioeconomics of Sea Bass Production

Species diversification is one factor that will help stabilize the aquaculture industry and sea bass culture offers such an opportunity. The profitability of sea bass aquaculture was assessed to entice fish farmers to go into this venture. A 10-year discounted cash flow projection indicates that a floating cage sea bass broodstock farm could be an economically viable enterprise (Agbayani, personal communication).

GROUPERS

Species Identification and Market Survey

Guides to grouper classification in the Philippines (Kohno 1986, 1987a) and in Southeast Asia (Kohno et al. 1990) had been published. Forty-six species from 7 genera were listed. Species identification was based on color patterns.

A fry collection survey (Solis, unpublished results) showed that grouper fry were most abundant in October with *Epinephelus suillus* and *E. megachir* as the dominant species. *E. suillus* fry were usually caught along channels of inshore waters while *E. megachir* on rocks close to open waters.

To identify the species available for aquaculture, species composition and abundance in grouper catch landed in lloilo central market was monitored from April to October 1987 (Kohno and Duray 1989). Of the many grouper species found, *E. suillus* followed by *E. megachir* are the dominant species (Kohno and Duray 1989).

Breeding

The orange-spotted rockcod (*E. suillus)* is a protogynous hermaprodite; sex inversion to male may occur at the age of seven years. The induction of sex reversal through hormone therapy is, therefore, vital to grouper propagation and culture. Regardless of the dose applied, only females weighing at least 1.2 kg undergo spermatogenesis after 3 months of biweekly injections of MT (Tan-Fermin et al. 1990). However, milt is obtained from both vehicle- and MT-treated fish six months after treatment. Seven monthly implantations of MT in silastic capsule did not induce sex inversion in 3-9 kg fish (Castillo, unpublished results). Allowing intraspecific interaction of *E. suillus* of different sizes in communal tanks for 11 weeks resulted in 4% of juvenile female grouper developing ovotestes (Tan-Fermin, unpublished results).

A single injection or pellet implantation of LHRHa plus MT did not induce *E. suillus* to spawn (Castillo, unpublished results). However, *E. suillus* spontaneously spawned in concrete tanks and in cages starting July 1990 (Toledo et al. 1990). Sequential, spawnings occurred 5-10 times monthly. Spawnings were recorded late in the afternoon (1600 to 1800H) within four days before or after the last quarter moon phase.

Nursery

Larval rearing trials carried out for some grouper species over the past decade have had limited success. For *E. suillus,* similar results have been obtained at SEAFDEC/AQD by Nagai (1990) and Nagai et al. (1990). Preliminary data indicated an optimum stocking density of 10-20 larvae per liter. Oyster eggs, artificial plankton, or a combination of these with rotifers have been tried for larval rearing, but with little success (Nagai 1990). A practical diet containing 30% soybean meal, 25% squid meal, and 25% squid liver meal gave optimum survival and growth rates in grouper fry (3.8-5.1 cm total length) (Nagai et al. 1990). High survival (92-97%) was attained when grouper fry (1.0 g BW) were fed minced fresh fish alone or in combination with fermented soybean meal. A 39% survival resulted when grouper fry (03 g BW) were weaned to formulated diet using fermented soybean meal as attractant; lower survival rates were obtained using either shrimp meal paste, squid meal, or squid liver meal as attractants (Nagai 1990).

Grow-out Culture

Kohno et al. (1988) reviewed the grouper culture practices in the Philippines. The existing culture method is usually based on the fishfarmers' own experience. Grouper culture is done in ponds or in cages. The most popular and desirable cultured species is *E. malabaricus (= E. suillus).* Increased production is constrained by insufficient fingerlings supply and lack of reliable culture technique. Kohno et al. (1989) investigated the effect of feeding rations and feeding frequencies on *E. suillus* in ponds. From an initial weight of 110-130 g, *E. suillus* can attain the marketable size (500 g) in 12 weeks, when fed trash fish at 5% BW once daily.

Disease Control

Cage and tank-held broodstock and juveniles of *E. suillus* were infected by *Vibrio.* Injured fish died when continuously exposed for 96 h to the bacteria. Intramuscular injection of oxytetracycline-HCl at 25 mg/kg BW for 5 consecutive days controlled the infection (Lavilla-Pitogo et al. in press).

SNAPPERS

Species Identification

A survey of snappers common in lloilo markets revealed 13 species, the most abundant of which are: *Lutjanus decussatus, L. fulviflamma, L. vitta, L. carponotatus, L. malabaricus, L gibbus,* and *L. fulvus* (Cheong, unpublished results).

SUMMARY

Spawning and egg production of sea bass have been maximized as a result of additional information on optimum dose, minimum egg size responsive to induction, timing of hormonal application, advancement of sexual maturation, and the shelf-life of LHRHa. Based on the results from recent studies, the stocking density, feeding and water management schemes for sea bass larval rearing have been modified to reduce cannibalism and improve survival. Sea bass nursery techniques under various conditions (tanks, ponds, and cages) are presently being investigated.

The spontaneous maturation and natural spawning of grouper (*E. suillus*) have paved the way for the development of reliable larval rearing techniques for this species.

Notwithstanding recent advances, many more aspects of sea bass, grouper, and snapper biology and culture require study: a) diseases of sea bass and grouper in captive broodstock and in the hatchery, b) cost-effective feeds from larval to grow-out stages, c) development of male spawners for sea bass and grouper, and c) broodstock development techniques for snapper.

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In:F Lacanilao, RM Coloso, GF Quinitio (Eds.). Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia and Prospects for Seafarming and Searanching; 19-23 August 1991; Iloilo City, Philippines. SEAFDEC Aquaculture Department, Iloilo, Philippines. 1994. 159 p.

MILKFISH, RABBITFISH, AND MULLET

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ABSTRACT

This paper reviews studies conducted on milkfish (*Chanos chanos*), rabbitfish (*Siganus guttatus*), and mullet (*Mugil cephalus*) at the SEAFDEC Aquaculture Department from 1968 to 1991. Milkfish studies focused on hormonal induction of off-season gonadal maturation, dietary manipulation of milkfish broodstock to improve egg and larval quality, improvement of larval rearing techniques for mass fry production and technology transfer to the private sector, and search for a low-cost, practical diet for milkfish and a supplemental diet to increase pond production. Preliminary success on alternate feed for larval rearing and spontaneous maturation of milkfish in concrete tanks may help alleviate milkfish fry supply in the future. Studies on rabbitfish centered on improvement of larval survival and search for the optimum diet for growth of rabbitfish fry and juveniles reared in ponds. The difficulty in rearing rabbitfish larvae due to high mortality at first week after hatching hinders the development of the rabbitfish industry. Research involving mullet was solely on the establishment of broodstock for fish propagation.

INTRODUCTION

Milkfish *(Chanos chanos* Forsskal), rabbitfish *(Siganus guttatus),* and mullet *(Mugil cephalus)* provide cheap sources of protein for Southeast Asian countries. However, the culture and production of these fishes are hindered primarily by the unpredictable and seasonal seed supply and lack of available practical diet. Since 1976, initial studies were conducted at the Aquaculture

Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD) to generate economically feasible seed production and culture techniques for milkfish, rabbitfish, and mullet. From 1988 to 1991, continuing research on these fishes focused on their propagation, nutrition and feed development, pathology, and culture. This review deals with the results of those research studies. It is hoped that these achievements will provide more materials for the generation of a sustainable propagation and culture techniques for these fishes.

MILKFISH

Breeding

Milkfish breeding studies aimed to increase production of good quality eggs through improved maturation and breeding techniques. Implantation of reproductive hormones has been widely used to induce gonadal maturation in teleosts (Crim 1985, Lam 1985). Testosterone implantation with or without luteinizing hormone-releasing hormone analogue (LHRHa) has no marked effect in inducing early sexual maturity (Marte et al. 1989a). In a separate unpublished study, implantation of pelleted methyltestosterone (MT) and LHRHa also fails to induce precocious sexual maturation in contrast to previous report (Lee at al. 1986). A present study using estradiol-17β (E_2) implants produced slightly better results. Milkfish reared in 150- and 200-ton concrete tanks and given E_2 implants alone five times in a year had the most number of maturing and mature females at the end of the spawning season (October) and at the start of the succeeding season (March) than those given E_2 and LHRHa, LHRHa alone, or cholesterol pellets (control. Spontaneous spawning was observed in April a few weeks ahead of the unimplanted controls reared in a separate tank, but since hormone-treated and cholesterol-implanted control fish were reared in the same tank, it was difficult to determine which females spawned.

Recently, spontaneous spawning of milkfish in concrete tanks (Emata and Marte 1990) provides an alternative for milkfish spawning in floating net cages which is site-specific. Furthermore, it allows photoperiodic manipulation to induce off-season maturation.

Induced spawnings of mature milkfish are observed 16-49 hours post-injection in all females given human chorionic gonadotropin (1,000 international units per kilogram body weight) and 87% of females given mammalian gonadotropin-releasing hormone (10 micrograms per kilogram) or salmon gonadatropin-releasing hormone analogue (GnRHa) (100 μg/fish) (Marte et al. 1988b). Induced spawning through pellet implantation of GnRHa are less effective at 100 μg/fish. Induced spawning runs in 1990 indicate that spawning tank size can influence successful embryonic development of spawned eggs resulting in hatched larvae (Emata and Marte 1990).

A female specific protein, vitellogenin, with molecular weight of 400 kiloDalton comparable to those found in other teleosts (Hara and Hirai 1982), had been identified in milkfish (Garcia, unpublished results). Further studies on this protein can provide more information on milkfish reproduction.

The breeding technology generated by SEAFDEC/AQD following spontaneous spawning in cages (Marte and Lacanilao 1986) is verified in the National Milkfish Breeding Program. However, in its terminal phase in 1988, spawnings were observed in only 4 out of 13 sites nationwide with very few eggs collected.

A manually-operated sweeper-type egg collector (Garcia et al. 1988) coupled with a fine mesh net lining (Marte 1988) have significantly increased egg collection in floating net cages. Eggs can be transported at a density of 6,000 eggs/1 at 28°C and 28 ppt to maintain high survival (Garcia and Toledo 1988). These techniques can ensure sufficient quantity of viable eggs for hatchery runs.

Ongoing broodstock management studies focused on determining optimum dietary lipid levels to improve egg and larval quality. Several spontaneous spawnings have already occurred in this study but preliminary results appear inconclusive (Marte and Emata, unpublished results). Other broodstock management studies involve determining the influence of several factors (i.e. sex ratio, source, and age) on egg production and egg and larval quality.

Nursery

Nursery studies centered primarily on mass production of hatchery-produced fry. Modified water management and feeding schemes at larval rearing were conducted to test their effectiveness (Gapasin and Marte 1990). Following preliminary trials, heavy mortality occurred at Day 3 in larvae reared in a flow-through system stocked at 90 larvae per liter (Duray, unpublished results). However, resulting larvae were found to be more robust than those reared in a static system (control) stocked at 30 larvae/1.

Continuing tests for an alternate feed to supplement live food *(Brachionus* and *Artemia)* for milkfish larvae initially show that milkfish larvae fed combined microparticulate feed and rotifer, *Brachionus,* are significantly bigger than those fed microparticulate diet or *Brachionus* alone (Marte and Duray 1991). In a subsequent study, milkfish larvae fed microbound diet containing highly unsaturated fatty acid (kappa-carragenan microbound diet) as a supplement to live food and sampled on Day 21 have significantly higher body weight than those of larvae fed another supplemental microbound diet (Nosan R-l) or live food *(Brachionus* and *Artemia)* alone (Marte et al., unpublished results). Further studies are needed to verify these results.

A comprehensive study on feeding biology showed that from Day 3 to Day 21, milkfish larvae initially consumed an average of 4±3 *Brachionus* individuals daily with the number ingested increasing with larval size (Duray, submitted). Day 7, 14, and 21 larvae commenced feeding right before light onset (0400-0600 H) and exhibited 3-4 feeding peaks during the day. These results may avoid mass mortality through improved feeding management.

Hatchery verification of SEAFDEC/AQD-generated technology for milkfish mass fry production (Gapasin and Marte 1990) in collaboration with the private sector is being conducted. Initial hatchery runs revealed heavy mortalities beginning Day 6 probably due to inadequate supply and feeding of live food (Garcia et al., unpublished results).

Physiological studies on metabolism indicated that milkfish weighing 20-50 and 150-250 grams had maintenance ration of 5.2 and 4.9 g $kg^{-0.8}$, respectively, when fed diets containing 41% protein (Schroeder, unpublished results). From oxygen consumption of 20-50 g milkfish in 26-28°C rearing temperature, the standard metabolic rate, routine metabolic rate, and scope for spontaneous activity were 160-250, 260-330, and 200-350 mg O_2 h^{-1} $kg^{-0.8}$, respectively (Schroeder, unpublished results). These values can determine growth potential of milkfish similar to that of tilapia (Becker and Fishelson 1990).

Deviations in plasma osmolality and chloride concentrations of milkfish juveniles (40-260g BW) taken 0,1,2,3,5,7 and 14 days following abrupt transfer from seawater (32 ppt) to salinities of 0,16,32 (control) and 48 ppt are proportional to the osmotic or ionic gradient but inversely proportional to size (Ferraris et al. 1988). These results suggest that while smaller fish adapts to freshwater better than to seawater, larger fish adapts to seawater better than to freshwater. These osmoregulatory adaptations may reflect natural habitat shifts during development.

Recruitment mechanism of milkfish fry along the coastline remains debatable. Newly-collected milkfish fry had very low feeding incidence in spite of the abundance of plankton (Morioka, unpublished results). In contrast to previous reports (Kumagai 1984), a regular increase in the total length of milkfish fry collected at various moon phases has not been observed (Morioka, unpublished reports).

Milkfish fry given *Tetraselmis tetraheli-* or *Isochrysis* galbana-fed *Brachionus* have higher growth rates than fry given *Chlorella* sp.-fed *Brachionus* (Villegas et al. 1990). The high protein and fat levels of the two algal species may have enhanced the dietary value of *Brachionus.* In a separate study, milkfish fry fed water flea *(Moina macrocopa* Strauss) have better growth than those fed *Brachionus* (Villegas 1990). Fry given frozen *M. macrocopa* has significantly lower growth and survival than those of fry fed live moina (Villegas and Lumasag 1991). But both parameters are unchanged when fry were given live or frozen *B. plicatilis.* The suitability of using frozen rotifers allows short term storage in anticipation to high hatchery demand and overcome any difficulties arising from failure to mass produce *B. plicatilis.* However, milkfish fry dealers presently do not use live food when storing fry (Bagarinao 1991).

Nutrition and Feed Development

Significant achievements on nutritional studies have been obtained to warrant initial formulation of a practical diet for milkfish which has been a major concern of the Feed Development Section. Milkfish fingerlings require a diet of 30-40% protein, 10% fat, and 25% carbohydrates (Alava and Lim 1988, Piedad-Pascual 1989). Energy levels exceeding 3,500 kilo calories per kilogram do not improve weight gain. Amino acid-supplemented diets containing protein-energy ratio to total metabolizable energy ratio of 44% promote highest growth rates of milkfish juveniles compared with any of the other ratios (Coloso et al. 1988).

Based on dry diet, the optimum growth requirements of milkfish juveniles for essential amino acids are: lysine, 2.0%: arginine, 2.1 %; threonine, 1.8%; histidine, 0.8%; isoleucine, 1.8%; leucine, 2.3%; valine, 1.6%; and phenylalanine, 1.9% at tyrosine level of 0.45% and 1.3% at tyrosine level of 1.20% (Borlongan and Benitez 1990, Borlongan 1991, unpublished results). The growth potential of a particular dietary protein source can be determined from the closeness of its amino acid profile to the growth requirements.

Milkfish has a total lipid content of 4.5% to 4.9% (Bautista et al. 1991). Lipids consist mainly of neutral type, primarily triglycerides and cholesterol ester. Essential fatty acid requirements of milkfish indicate that (n-3) fatty acids such as 18:3(n-3) and (n-3) highly unsaturated fatty acids are nutritionally more important than 18:2(n-6) (Borlongan, in press).

Milkfish fingerlings fed diets containing 10% vegetable protein had significantly higher growth rates, protein efficiency ratio, and survival rates than those given animal protein-containing diets. Fingerlings fed mung bean-containing diets also had higher *in vitro* protein digestibility than animal protein-containing diets (de Costa Reis, unpublished results).

Digestive lipases of milkfish have an optimum temperature range of 50-60°C (Borlongan 1990). The depressed lipase activity at 0-25°C, similar to those of amylase and protease, may account for the decreased feeding activity of milkfish cultured during cold months resulting in considerably slower growth.

Under grow-out conditions, a fish meal-based formulated diet promotes higher growth rate of fingerlings than those given *Oscillatoria* that were inoculated and grown in the ponds and with or without formulated diets (Santiago et al. 1989). Fingerlings fed formulated diet also have higher growth rate than those given *Spirulina* powder and formulated diet or rice bran alone.

Pathology

Tolerance tests showed milkfish fingerlings have median lethal concentrations of 332, 260, 241, and 232 parts per million formalin at 24, 48, 72, and 96 hours bioassays, respectively (Cruz and Pitogo 1989). Milkfish fingerlings exhibit median lethal concentrations of 1.48 and 1.49 milligrams per liter potassium permanganate at 24 and 48 h bioassays, respectively (Cruz and Tamse 1989).

Aeromonas hydrophila infection have incurred heavy mortalities of milkfish juveniles freshly stocked in freshwater pens. Milkfish vaccinated with antigens obtained from a pool of 5 strains of *A. hydrophila* screened from naturally occurring milkfish did not develop protective immunity (Po, unpublished results). Current research will test immunogenecity of antigens from a single strain of *A. hydrophila.*

Farming Systems

Economic analysis of the modular pond system, which can increase croppings up to 7 times annually, shows higher profitability levels compared to the straight-run method. This system has a return of investment (ROD of 69% and payback period of 1.25 years (Agbayani et al. 1989) compared with the 56% ROI and 1.37 years payback period (Bombeo-Tuburan et al. 1989) of the straight-run method.

Economic analysis of an integrated milkfish broodstock and hatchery operation as a public enterprise shows negative figures on economic indicators (net present value and internal rate on return) up to the fifteenth year (Agbayani et al. 1991). However, both indicators show upward trends beginning on the seventh year. The high investment in hatchery facilities and low utilization of hatchery facilities because of short spawning season (April to October) may have caused the poor economic indicators. The discounted cash flow computations were based on an annual stocking of 100 milkfish juveniles for 4 years, egg production beginning on the fifth year, and revenues solely coming from the sales of fry. However, increased survival in the mass production of milkfish fry resulting from better broodstock nutrition and effective larval management may shorten the payback period.

At higher stocking densities (6,000 and 9,000 per hectare) of milkfish juveniles, supplemental feeding at the last month of culture increases yield than feeding natural food alone (Sumagaysay et al. 1990). Supplemental feeds containing 22.0% and 27.4% protein increase growth, yield, and net profit than those of fish given rice bran or unfed (Sumagaysay et al. 1991). Survival of milkfish given supplemental feeds or none are similar. Following 4 months of culture, the concentration of metabolites in the culture water is low in all treatments but the level of total carbon dioxide and nitrite-nitrogen increase significantly as biomass increases. The organic matter in supplemental feeds can be replaced with rice straw compost of up to 50% without affecting growth and yield (668-725 kilograms per hectare) but doubling the net income (Sumagaysay 1991). Growth and yield decrease significantly with 75% replacement. The compost is not a satisfactory feed substitute as fish derive most of its nutrition from formulated feeds. However, addition of rice straw compost enhances fertilization rate in ponds leading to higher production of autotrophic and heterotrophic microorganisms which will compensate for decreasing nutrient output. At a feeding rate of 1.75% BW using low protein (23.8%) supplemental feed, the 50% replacement of dietary organic matter with rice straw compost is an innovative way of reducing feed cost and increasing net profit. Even the addition of dietary fiber (33%, mostly from rice hull), a low protein supplemental diet (14%) given 25 days after stocking can be an economical way of increasing milkfish production in brackishwater ponds as it greatly reduced cost of feed input (Sumagaysay and Chiu-Chern 1991). Further studies are needed to formulate a suitable supplemental feed at certain pond productivity and environmental condition.

Modifications of culture practices to increase production and profitability were conducted. Stunting of milkfish fingerlings does not affect growth, survival, and net production, but the practice provides year round supply of fingerlings (Bombeo-Tuburan 1988). The silo method of fertilizer application, where fertilizer is placed in a sack and submerged in the pond for gradual release, does not increase fish production and growth over the broadcast method (Gerochi et al. 1988), but the former method is cheaper, less laborious, and produces consistent growth of *lablab* (matrix of micro and macrobenthic organisms) than the latter method. Application of 50 kg organic fertilizer/ha and biweekly water replenishment are recommended for better growth, survival, and gross production (Bombeo-Tuburan 1989). In a separate study, 50 kg organic fertilizer/ha and 15 kg inorganic fertilizer/ha do not significantly increase yield but give more profit than any of the other fertilizer and dosage combination tested (Bombeo-Tuburan 1989).

RABBITFISH

Breeding and Nursery

Two injections of 2 international units human chorionic gonadotropin per gram body weight given 24 hours apart induce spawning of female rabbitfish (Ayson 1991). Hormone injections are given to females with average oocyte diameters less than 0.46 mm which can normally spawn naturally. The number of eggs spawned (424,000 per female), fertilization rate (96%), and hatching rate (59%) are similar between artificial and natural spawning.

Broodstock management studies on rabbitfish initially attempted to enhance survival of rabbitfish larvae. Stress due to handling and repeated injections significantly enhances spawning but has no effect on larval survival (Ayson 1989). Rabbitfish given diets containing 18% lipid have significantly higher number of normal larvae with increased survival rate than those of fish given diets containing 12 or 15% lipid (Hara et al. 1986). The significance of dietary lipid was also demonstrated in rabbitfish fed diets enriched with cod liver and soybean oils. All rabbitfish females given lipid-enriched diets produce mature eggs monthly for five consecutive months, while females given lipid-poor diets intermittently produced mature eggs (Emata, unpublished results).

Hormonal manipulation of sexually mature rabbitfish to enhance larval quality and improve survival was also tested. A single thyroxine injection given to broodfish a day or two prior to spawning significantly increased thyroid hormone concentrations in the plasma of female rabbitfish, in spawned eggs, and in newly-hatched larvae but did not enhance larval development and survival rates (Ayson and Lam, submitted) in contrast to previous reports (Lam 1980, Brown et al. 1988).

Mass mortality of rabbitfish larvae within days following hatching occurs at the transition from endogenous to exogenous feeding. Kohno et al. (1988) indicated that the larvae must be able to start feeding in order to survive.

However, the conditions for successful feeding transition are still unknown. Rabbitfish larvae reared at continuous light have higher mean survival (31%) and bigger larval size at first feeding than those reared under natural daylight (17%) (Duray and Kohno 1988).

Under simulated transport conditions, survival of rabbitfish fry at 100 fry/1 under ambient conditions of 28°C and 32 ppt is not adversely affected by up to 8 hours of transport (Ayson et al. 1990). Stocking densities greater than l00 fry/1 shortens transport time to maintain survival rate of 96%.

Nutrition and Feed Development

Nutrition studies focused on determining the optimum protein requirements for growth of rabbitfish larvae, fry, and juveniles. Diets containing 39, 41, 51, or 56% protein promote better growth of 25-day old larvae than *Artemia* alone (Parazo 1991). However, weight gain, metamorphosis, and survival rates do not vary among protein levels. A diet of 35% protein and 3,832 kilocalories per kilogram-gave highest growth rate and protein efficiency of rabbitfish fry (Parazo, unpublished). A supplemental diet containing 26% protein gave higher average body weight (81.6 g) of rabbitfish juveniles in ponds than those given diets containing 21% protein (555 g) or fed *lumut* (48.8 g) (Bombeo-Tuburan, unpublished results).

MULLET

Breeding

A captive broodstock for mullet was established with 30 wild spawners in a 6-meter diameter by 3-meter deep floating net cage. Sexually maturing fish were observed in November, but spontaneous spawning was never observed probably due to stress following monthly samplings (Quinitio, unpublished results).

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TILAPIA, CARP, AND CATFISH

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ABSTRACT

Research activities on tilapia focused on *Oreochromis niloticus* and red tilapia. Experiments include developing new experimental and statistical procedures for strain evaluation, development of a stable reference strain, development of a high-yield red tilapia strain through introgressive hybridization, comparison of fish growth in different environments relevant to aquaculture, development of an index for routine monitoring of salinity tolerance of existing tilapia strains/experimental stocks, evaluation of nutritional requirements of red tilapia, and determination of heavy metal contents of tilapia in Laguna de Bay, Luzon, Philippines.

Research on carp *(Aristichthys nobilis)* and catfish *(Clarias macrocephalus)* were focused on improvement of methods for induced spawning, development of seed production techniques, and nutritional requirement of bighead carp fry and broodstock.

INTRODUCTION

Red tilapia and Nile tilapia *(Oreochromis niloticus)* have become popular species for aquaculture in Asia. These were identified as priority species for SEAFDEC research during the First Seminar on Aquaculture Development in Southeast Asia (ADSEA '87). The genetic improvement of these species is now a major concern of many universities and international and regional research institutions.

Successful attempts in induced spawning and year-round sexual maturation in floating net cages (Fermin 1990) have made bighead carp *(Aristichthys nobilis)* a popular aquaculture fish in the 90,000-hectare Laguna Lake in Luzon, Philippines. To date, there are 16 private carp hatcheries around Laguna Lake.

Breeding of the freshwater Asian catfish *Clarias macrocephalus* in captivity has been reported by Hara (1977), Carreon et al. (1976), and Ngamvongchon et al. (1988). However, catfish culture in the Philippines is still hampered by the lack of fingerlings.

This paper presents the results of studies on tilapia, carp, and catfish at SEAFDEC/AQD from 1988-1991.

TILAPIA

Hatchery, nursery, and grow-out techniques for tilapia *(Oreochromis niloticus)* developed at the SEAFDEC Aquaculture Department (SEAFDEC/AQD) are reviewed in Fermin (1988) and Carlos and Santiago (1988). Bautista et al.(1988) reported that a male to female ratio of 1:4 is most efficient for all types of breeding facilities.

Strain Comparison Procedures

An important objective of any fish breeding program is to develop genetically superior strains. Comparison experiments at SEAFDEC/AQD involve rigorous size grading (collimation), use of full-sib groups for comparison, and inclusion of internal reference fish in each replicate tank for statistical control.

Size-grading or "Collimation". Test strains (Nile tilapia) and reference strain (red tilapia), of approximately the same age, were matched as closely as possible based on their lengths at the start of every experiment for accurate measurement of size-specific growth.

Full-sib Groups. Each full-sib family was matched with equal size and equal number of red tilapia.

Internal Reference Strain. The usual strain comparison study involves analysis of variance (ANOVA). The internal reference procedure uses an analysis of covariance (ANCOVA) in which growth of reference fish (red tilapia) is the concomitant variable to reduce error variance caused by environmental variation like population density and food supply (Basiao and Doyle 1990a).

The first attempt to use red tilapia as an internal control showed a significant statistical interaction between the internal control and the test strains (Basiao and Doyle 1990a). The statistical procedure of using an internal reference is feasible only if there is no biological interaction between the test and the reference fish (Doyle et al. 1990).

Comparison in Diverse Environments

Strains were compared in high-input, well managed environments as well as low-input and marginal or artisanal conditions. Tilapia strains show significant genotype effect during a three-week temporary crowding period (Basiao and Doyle 1990b) and at the end of the final grow-out period in hapa cages in Laguna de Bay (Basiao, unpublished results).

No genetic variation in growth is found in Nile tilapia strains held in freshwater for two weeks, acclimated for four days in a salinity of 32 parts per thousand and reared in 32 parts per thousand seawater for two weeks (Basiao, unpublished results).

Genotype-environment interaction can be an important factor in selecting fish under various aquaculture conditions. Romana-Eguia and Doyle (1992) found indications of genotype-environment interaction among three Nile tilapia strains reared on low (rice bran) or high (commercial diet) quality feeds. These strains also differ in their growth response under a restricted or non-restricted feeding regime (Romana-Eguia, personal communication). However, ranking of the strains are similar in the two feeding regimes.

Index for Monitoring Salinity Tolerance

Based on mean survival time (MST) and median survival time (ST_{50}), freshwater-spawned and reared *O. mossambicus* and *O. mossambicus x O. niloticus* hybrids show higher salinity tolerance than *O. niloticus* (Villegas 1990a). Increased salinity tolerance with age or body size is also evident in the study.

Villegas (1990b) reported that the highest growth for O. *mossambicus* is at 15 and 32 parts per thousand while the optimum salinity range for growth of *O. niloticus* is 0-10 parts per thousand.

Mercury Levels in *O. niloticus*

A few pollution studies at SEAFDEC/AQD have focused on mercury levels in sediment, water, and selected fishes from Laguna de Bay. The mercury content of tilapia samples (undetectable to 0.1 parts per million) is below the maximum permissible levels of *05* parts per million set by the World Health Organization (WHO) and United States Food and Drug Administration (USFDA). Mercury levels in sediments range from 27 to 117 parts per billion, while water samples show low (undetectable to 0.5670 parts per billion) mercury levels (Cuvin-Aralar 1990).

Another study has shown that tilapia fry (0.042-0.081 grams body weight and 12-15 millimeters total length) exhibit hyperactivity and erratic swimming after exposure to varying mercury concentrations (Cuvin-Aralar 1991). Scoliosis, a curvature in the mid-trunk region, is significantly correlated with increasing mercury concentration (0.03-0.06 parts per million).

Nutrient Requirements

A study on the growth response of red tilapia fry to varying protein levels (25,30,35, and 40%) and protein to energy ratios (111,100, and 80 milligram per kilocalorie) shows that red tilapia fry attain highest weight gain at 40% protein diet with a protein to energy (P/E) ratio of 111 milligrams per kilocalorie (Santiago and Laron 1991). The study also shows that protein efficiency ratio decreases with increasing protein level.

A study on the amino acid requirements of Nile tilapia has shown that the essential amino acid requirement pattern is highly correlated with the essential amino acid composition of the muscle of the fish (Santiago and Lovell 1988).

Leucaena leucocephala and *Azolla pinnata* were tested as protein sources in formulated diets fed to Nile tilapia broodstock and fry. Santiago et al. (1988a) have shown that on the basis of fry production and growth, *Leucaena* leaf meal should not exceed 40% of the diet of Nile tilapia broodstock. Dried and finely ground *Azolla pinnata* was found to be a desirable component of feeds for Nile tilapia fry (Santiago et al. 1988b). Growth of fry increases as the level of the dietary *Azolla* meal increases.

CARP

Experiments on bighead carp were conducted to refine the induced spawning techniques and determine the response to nutrient level and feeding regimes.

Induced Spawning

Studies to further improve the techniques of induced spawning were undertaken (Fermin 1988). Bighead carp broodstock with mean body weight of 25-5.4 kilograms were induced to spawn with intraperitoneal injections of varying combined dosages of human chorionic gonadotropin (HCG) and luteinizing hormone-releasing hormone analogue (LHRHa) (Fermin and Reyes 1989). Fish were spawned successfully following a single or double injection of 1,800-2,000 international units HCG in combination with 10,15, or 20 micrograms LHRHa per kilogram body weight (Fermin and Reyes 1989).

In a related study, a combination of 75 micrograms LHRHa/kilogram body weight + 15 milligrams DOM (domperidone)/kg BW given at two injections is likewise effective in inducing bighead carp to spawn. However, injection protocols using LHRHa + DOM have lower combined cost than HCG + LHRHa (Fermin 1991).

Lake-reared bighead carp broodstock were induced to spawn using LHRHa, LHRHa + RES (reserpine), LHRHa + HCG, and HCG alone. LHRHa + HCG give the highest mean fertilization (90%) while the lowest (32%) is obtained with LHRHa only (Gonzal, personal communication). Induced spawning protocol using LHRHa + HCG gave the highest (79%) mean hatching rate while HCG alone gave the lowest (28%). Incubations were done at 26.8 °C and water hardness of 300-500 milligrams/liter $CaCO_3$.

Nutrient Requirement and Feeding

A study of different feeding regimes has shown that bighead carp fry fed combination of *Brachionus* and artificial diet containing 41.5% crude protein and 11.9% crude fat have the highest growth, but survival rate is highest for fry fed *Brachionus* alone (Santiago and Reyes 1989). Fermin and Recometa (1988) also found that artificial diet in combination with *Brachionus* and *Moina* is best for growth of bighead carp fry. A feeding rate of 30% body weight is most suitable for bighead carp fry fed artificial diet (Carlos and Santiago 1988).

Santiago and Reyes (1991) found 30% dietary protein as optimum level for maximum growth of young bighead carp fed isocaloric diets of varying protein levels. The survival rates do-not differ significantly among treatments while feed conversion ratio and protein efficiency ratio do not clearly indicate the required protein level.

Bighead carp fry perform better on diets containing 3,130-3,470 kilocalorie metabolizable energy per kilogram and P/E ratios of 92 and 100 milligrams protein per kilocalorie (Trono-Legiralde 1990). The 37% protein diet with approximately 3,470 kcal metabolizable energy produces maximum growth. Of the levels tested, 4.26% dietary lipid and 42% carbohydrate are best for bighead carp fry.

A study of various feeding treatments (40% protein diet, 20% protein diet, and no artificial diet or control) revealed that artificial diet does not hasten the growth and maturation of 10.5 month old bighead carp stocked in floating cages in Laguna Lake (Santiago et al. 1991). This finding supports an earlier observation that bighead carp sexually mature year-round without supplemental feeding in floating net cages in Laguna de Bay (Fermin 1990). However, fish fed 40% protein diet have the highest mean total weight of eggs/female, total number of eggs/spawning, and number of eggs/kilogram body weight. The study shows that fry of the fed broodstock have higher survival rates than fry of the unfed broodstock when deprived of food for up to ten days.

Sexual maturation in two-year old bighead carp reared without supplemental feeding in 12.5 x 10 x 3 meters floating net cages in Laguna de Bay was observed year round (Fermin 1990). High maturation rates in both sexes are positively correlated with high inorganic turbidity in the lake.

CATTISH

Clarias macrocephalus mature but do not spawn in captivity. There is a need to study induced oocyte maturation and ovulation to provide a steady supply of seed for the industry.

Captive catfish (39-167 grams body weight) can be induced to undergo oocyte maturation and ovulation at 15-16 hours after simultaneous injection of

0.01-0.10 micrograms LHRHa and 1 microgram pimozide (PIM)/gram body weight (Tan-Fermin, in press).

A study (Tan-Fermin 1991) on the suitability of different formalin-containing fixatives for C. *macrocephalus* eggs showed that one percent phosphate-buffered formalin is the most suitable fixative. The osmotic pressure of one percent buffered formalin is not significantly different from the catfish plasma.

RESEARCH IN PROGRESS FOR 1991

Activities on tilapia include 1) developing the best practical procedure for the comparative evaluation of genetic strains of tilapia in small to medium-sized facilities, 2) comparison of fish growth in contrasting lake environments, 3) development of a stable reference strain and refinement of techniques for using internal reference fish, 4) development of an improved strain of red tilapia through introgressive hybridization, and 5) evaluation of heavy metal tolerance and uptake of different tilapia strains.

On-going activities on carp and catfish include broodstock and breeding management of bighead carp and improvement of induced breeding and seed production techniques for catfish.

RECOMMENDATIONS

The need to develop strains in diverse environments is worth considering in selection programs. We must learn our lesson from the Green Revolution in field crop production where development of new varieties led to the increased use of fertilizers and pesticides. In most cases, this has become detrimental to the poorer sector of society and very costly to the environment. Strains or breeds that will perform well in artisanal conditions will not only benefit small-scale or artisanal fisherfolk but will also help preserve our environment.

Refinement of hatchery techniques for red tilapia and catfish is needed to increase production. Likewise, feed development for nursery and grow-out of red tilapia, catfish, and bighead carp also needs further studies. Broodstock and breeding management schemes of bighead carp have to be re-evaluated to verify reports of slow growth that is attributed to inbreeding.

ACKNOWLEDGMENT

The support of the International Development Research Centre of Canada for the Tilapia Genetics and red tilapia nutrition studies is gratefully acknowledged.

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SHRIMPS

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ABSTRACT

During 1988-1991, research at the Aquaculture Department of SEAFDEC on the shrimp *Penaeus monodon* has been directed towards a) the development of captive broodstock, b) the refinement of hatchery and grow-out techniques, c) the development of diets for the various stages of culture, and d) the prevention and control of diseases. Biochemical, morphological, and histological characterization of the male and female reproductive systems were conducted to provide basic information for the development of techniques for pond-reared broodstock. Studies on the refinement of hatchery techniques included determination of the environmental and feeding requirements of larvae and postlarvae to serve as basis for the improvement of management practices. Refinement of grow-out techniques included studies on the physiological response of this species to vital environmental factors and studies on the role of natural food organisms during culture. Nutrition studies have resulted in the formulation, testing, and improvement of diets for broodstock, larvae and postlarvae, juveniles, and subadult shrimps. Methods of prevention and control of the luminous bacterial disease, chronic soft shell syndrome, aflatoxicosis, *monodon baculovirus* (MBV) infection, and other relevant diseases have been investigated through the identification of causative agents and bioassay of possible chemo-therapeutants.

Studies to improve larval rearing of alternative shrimp species such as *P. indicus, P. merguiensis,* and *P. japonicus* have likewise been pursued. Nutritional requirements of the white shrimp species were evaluated to develop suitable formulated feeds for the different culture stages.

INTRODUCTION

Shrimp culture remains to be a fairly lucrative venture despite decline in prices. Like many growing industries, it is beset with diverse problems. Among the most pressing of these are the fluctuating and decreasing market price, occurrence of diseases in all phases of shrimp culture, and the dwindling supply of wild spawners or shrimp broodstock. Studies at the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD) during the last 4 years were focused on improvement of techniques towards more cost effective culture methods, disease control or prevention, and development of captive broodstock to address these problems and respond to the needs of the industry.

TIGER SHRIMP

Breeding

Induced maturation of *P. monodon* is usually achieved through ablation of one eyestalk. However, hatching rates of produced eggs are relatively low (Vogt et al. 1989). Hence, alternative methods which may elicit better reproductive performance were tested. Environmental manipulation through varying light quality was investigated as a possible factor influencing maturation. For unablated or ablated females, highest mean hatching rates of eggs and nauplii produced per female were obtained with green light and with the control (Primavera and Caballero, unpublished results). In addition, β-ecdysone and 17α-hydroxyprogesterone administration gave promising results in inducing maturation (Yashiro 1989).

Scarcity of spawners and declining number of adults from the wild, coupled with the inconsistent performance of larvae have spurred interest in developing shrimp broodstock in ponds. Studies on shrimp reproduction were conducted to develop techniques for growing captive broodstock. In one such study, Quinitio et al. (1990) isolated and described the ovarian protein vitellin and its related protein in the hemolymph, vitellogenin.

Based on histology and histochemistry, Tan-Fermin and Pudadera (1989) reclassified the existing stages of ovarian maturation into four: the previtellogenic, vitellogenic, cortical rod, and spent stages. For industry application, the ovarian width at the first abdominal segment must be measured to minimize arbitrariness; an ovarian width of at least 20 millimeter indicates readiness for spawning. There are no differences in the kind and appearance of oocytes in both ablated and unablated females. However, only the smallest (10-100 micrometer)or immature oocytes are left in the ovaries of unablated *P. monodon* after spawning. In contrast, larger (100-200 and 210-300 micrometer) oocytes in all stages of maturation are present in the ovaries of ablated females, indicating faster rematuration. Release of large but unripe oocytes during spawning may account for the low hatching rates obtained with ablated females (Tan-Fermin 1991, Vogt et al. 1989).

Lipid and protein levels (Millamena and Pascual 1990, Peñaflorida and Millamena 1990) in the ovaries were shown to significantly increase at early maturing to fully mature stages and decline at spent stage. Millamena and Pascual (1990) attribute the lipid increase to mobilization from the hepatopancreas to the ovary, while Peñaflorida and Millamena (1990) associated increases in ovarian protein concentration with synthesis of polypeptides, including yolk polypeptides, in the ovary. Amino acid and fatty acid (Peñaflorida and Millamena 1990, Millamena 1989, Millamena and Pascual 1990) profiles of the tissues were used to elucidate requirements of broodstock.

Studies on the early developmental stages of the reproductive system were done to determine the minimum age or size at which pond-grown *P. monodon* can be induced to mature or produce sperm. Results showed that primary oocytes can initially be observed among 2 to 3-month old female shrimps while early signs of spermatogenesis can be detected in 4- to 5-month old males (Toledo, personal communication).

Another study determined the effects of tags and tank color. Neither variable affects reproductive performance, but tagging causes a significant decrease in survival (Primavera and Caballero 1989).

Hatchery

The increase in number of hatcheries in the Southeast Asian region indicates that adoption of existing techniques for larval rearing is already economically feasible. Thus, studies concentrated on refinement of techniques to obtain consistent or higher survival or growth rates, lower production costs, or simplify rearing methods. Modification of the major activities affecting postlarval production were focused on water management and feeding practices.

Past methods using untreated seawater for rearing *P. monodon* larvae (SEAFDEC/AQD Working Committee 1984) have been revised to include pretreatment with chlorine and sodium EDTA (Parado-Estepa et al. 1991). EDTA improves survival by chelating heavy metals in the medium (Licop 1988) and chlorine significantly reduces bacterial populations in the water by 90%. Bacterial load builds up after 6 hours following neutralization, thus, use of treated water is highly recommended (Baticados and Pitogo 1991).

Larval rearing involves feeding of both artificial diets and phytoplankton. Several inexpensive protein sources were screened as possible substitutes for animal protein to lower cost of larval diets. These feed components were evaluated using an index based on the amino acid profile of whole tissues (Peñaflorida 1989). In addition, kappa-carrageenan microbound diet (C-MBD) was formulated (Bautista et al. 1989) and tested as larval food for *P. monodon.* In 40-liter culture tanks, natural food (NF) or C-MBD fed alone or in combination (NF+C-MBD) gives similar survival rates. However, verification tests in 10-ton tanks showed significantly higher survival with NF+C-MBD than natural food alone (Bautista et al. 1991).

Natural food is important for shrimp larvae; thus, several algal species were evaluated for nutritional quality. *Tetraselmis chuii* has higher protein and crude fat levels comparable to *Chaetoceros calcitrans* or *Skeletonema costatum* (Millamena et al. 1990b).

The optimal feeding levels using *Tetraselmis* was defined by determining the incipient limiting level (ILL) or the lowest food density to provide maximum ingestion rates at each substage. ILL increases with age of larvae until M_{III} and declines at postlarva 1. However, growth or percentage molting is significantly affected by food density only at the protozoeal substages (Loya-Javellana 1989). Therefore, *Tetraselmis* must be maintained at a density not lower than 10,000 cells/milliliter (ILL) at the protozoeal stage. For the mysis and postlarval 1 stages, 20,000 and 30,000 cells/milliliter (lowest densities tested), respectively, can be used and still attain comparable growth rates.

To overcome the problem of synchronization of natural food production with hatchery activities, Millamena et al. (1990a) developed a method for harvesting and preserving algae. Sun dried *Chaetoceros* or *Tetraselmis* proved to be acceptable to shrimp larvae.

Artemia is given at the mysis and postlarval stages. Tests showed that survival of postlarvae fed *Artemia* maintained on algae is higher compared with those fed *Artemia* maintained on ricebran (Millamena et al. 1988).

The pollution of culture water by excess feeds was demonstrated by Millamena (1990). Excess feed increases the biochemical oxygen demand (BOD), depresses dissolved oxygen (DO), and elevates NH_4-N and NO_2-N to levels detrimental to shrimp postlarvae.

Grow-out

Pond culture studies have focused on the refinement of techniques involved in extensive and semi-intensive methods. Growth of natural food in the pond can be enhanced through fertilization, which may also cause deterioration of soil or water conditions when applied indiscriminately. Comparison of fertilization schemes showed that biweekly application of 15 kilograms of nitrogen and 30 kilograms phosphorus per hectare with or without chicken manure increases shrimp yields (Subosa and Bautista l991a,b). Further increases in the amount of fertilizers do not improve yields.

Triño and Bolivar (1990) correlated shrimp production with the presence of lablab (a microbenthic complex of blue-green algae, diatoms, and microscopic plants and animals), lumut (composed mostly of filamentous green algae like *Chaetomorpha* and *Enteromorpha),* or digman *(Najas graminea)* in extensive ponds. Mean body weight and total production (kilograms) are highest in digman ponds. Primavera and Gacutan (1989) similarly found that juveniles fed live *N. graminea* attain highest survival and a high mean length compared with those fed either live or decaying *Ruppia maritima* or decaying *N. graminea.*

Studies related to semi-intensive culture concentrated on the improvement of supplementary diets for *P. monodon.*

Catacutan (1990) evaluated diets containing various carbohydrate levels based on survival, growth, and apparent digestibility. In another study, inositol, choline, and ascorbic acid were identified as the most essential vitamins for normal development of juvenile shrimps (Catacutan and de la Cruz 1989). Semi-intensive culture trials, however, resulted in similar survival or growth of shrimps fed diets with or without vitamins, suggesting that requirements may have been satisfied by the natural food (Triño et al. 1992).

Substitution of feed components to lower production cost of shrimps has been tested. Pascual et al. (1990) demonstrated that defatted soybean meal can replace up to 35% of animal protein. *Leucaena leucocephala* leaf meal as a protein source, however, is not suitable for shrimps (Pascual and Catacutan 1990).

Hemolymph calcium levels of P. *monodon* at different molt stages and salinities were investigated. Total hemolymph calcium is largely influenced by molt stage and to a lesser degree by salinity (Parado-Estepa et al. 1989).

Diseases

One of the major problems experienced by the shrimp industry during the past few years is the occurrence of diseases. In the hatchery phase, extensive mortalities occurred due to the luminous bacteria, identified as *Vibrio harveyi* and *V. splendidus* (Lavilla-Pitogo et al. 1990b). Chemical control against this disease was tested but appears to be limited because of the ineffectiveness and prohibitive cost of readily available drugs, and the morphological deformities produced in treated larvae (Baticados et al. 1990b). Thus, potential sources and routes of entry into the larval rearing system were identified to establish a set of preventive measures. Results showed that *V. harveyi* can enter the hatchery system mainly through the fecal matter from spawners, the seawater, or unwashed *Artemia* cysts (Lavilla-Pitogo et al. 1990a). These further suggest that breeders must be removed and the eggs washed after spawning to prevent infection of stock. Treatment of seawater and rinsing *Artemia* nauplii prior to use in the hatchery are also recommended.

Another disease of shrimps is caused by the *P. monodon-type* baculovirus identified by Baticados et al. (1991). Affected shrimps exhibit pale bluish-gray to dark-blue coloration, loss of appetite, and retarded growth (Baticados et al. 1990a).

The chronic soft-shell syndrome, a disease caused by several factors such as nutritional deficiency, presence of toxic elements, and poor water and soil conditions, affects juvenile and adult shrimps (Baticados et al. 1990a). This disease can also be induced by exposure to 1.5 to 150 parts per billion of the commonly used pesticide Gusathion A (Baticados and Tendencia 1991). Levels of calcium do not significantly vary between soft-shelled and healthy animals (Baticados et al. 1986). It was suggested that the Calcium-to-Phosphorus (Ca:P) ratio, and not calcium alone, may exert a greater influence on shell hardening. Subsequently, Bautista and Baticados (1990) showed that soft-shelling is reversed after feeding a diet containing a 1:1 Ca:P ratio.

Other diseases of shrimps are the shell disease (Lio-Po and Lavilla-Pitogo 1990) and red disease. The latter may be caused by aflatoxin or rancid feeds (Baticados et al. 1990a). Infection can be prevented by storing feeds in well-ventilated areas at a temperature of 10-20°C to retard oxidation (De la Cruz et al. 1989).

ALTERNATIVE SPECIES

Studies similar to those conducted for *P. monodon* were done for *P. merguiensis* and *P. indicus.* Changes in hemolymph vitellogenin levels during maturation (Quinitio, unpublished results), salinity tolerance of larvae (Yashiro, unpublished results), and pond culture using different densities (Mesa and Alava, unpublished results) are some of the studies being conducted for these species. Diets for all stages of *P. indicus* and *P. merguiensis* have been formulated and tested (Bautista, unpublished results; Peñaflorida, personal communication). For *Penaeus japonicus,* its life cycle in captivity was completed under Philippine conditions (Quinitio et al., in press).

CONCLUSION/RECOMMENDATIONS

One of the most urgent problem now facing the industry is the lack of *P. monodon* spawners or adults. Basic information from initial work must be considered and applied to the development of captive broodstock. For both *P. monodon* and alternative species, continued efforts must be exerted to refine hatchery and pond rearing techniques, with emphasis on maximizing cost effectivity.

Disease occurrence may continue to adversely affect the shrimp industry. Thus, research must also be directed towards finding immediate but practical means of disease prevention and control.

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BIVALVES

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ABSTRACT

Mollusc research at the Aquaculture Department of the Southeast Asian Fisheries Development Center from 1989 to 1991 was primarily focused on the highly exploited window-pane oyster, *Placuna placenta* Linnaeus. Other species studied were the saddle-shaped oyster, Placuna sella, the slipper-shaped oyster, *Crassostrea iredalei,* and the green mussel, *Perna viridis.* Research on *P. placenta* aimed to develop techniques in seed production (broodstock maturation and induced spawning), transplantation, and stock assessment and restocking of depleted natural beds. The annual variations in the reproductive activity, condition index, and proximate composition of P. *sella* were determined. A socioeconomic study of oyster (C. *iredalei)* and mussel (P. *viridis)* farming practices in western Visayas, central Philippines is on-going and will provide information on current culture methods and their profitability. An inventory of mollusc researches conducted in the Philippines has been done and the culture techniques and research gaps are being reviewed and identified. This information will guide further research on molluscs in the Philippines.

INTRODUCTION

Previous works at SEAFDEC Aquaculture Department (SEAFDEC/AQD) on mollusc were on the slipper-shaped oyster, *Crassostrea iredalei,* and the green mussel, *Perna viridis.* Techniques were developed to 1) increase collection of seeds from the wild, 2) improve farming techniques, 3)produce mussel and oyster seeds in the hatchery, and 4) improve sanitation and quality of bivalves (SEAFDEC, 1983). Some studies were also conducted on other species with high economic value, including the Asian-moon scallop *Amusium pleuronectes,* and the window-pane oyster, *Placuna placenta.*

During the first Seminar-Workshop on Aquaculture Development in Southeast Asia in 1987, four bivalve species namely *Pema viridis, Crassostrea iredalei, Anadara sp.*, and *Placuna placenta* were recommended as the priority species for research in 1989-1991. Research was to concentrate on: 1) resource evaluation, 2) site identification, 3) transplantation, 4) development of hatchery techniques, 5) spatfall forecasting, 6) refinement of grow-out techniques, 7) evaluation of culture technology, 8) depuration, and 9) product development and other uses. However, due to depletion of some *P. placenta* natural beds, mollusc research at SEAFDEC / AQD focused on first, with the primary objective of developing techniques in hatchery seed production, transplantation, and farming. At present, other research activities include studies on the saddle-shaped oyster *Placuna sella,* a socioeconomic study of oyster and mussel farming practices in western Visayas, Central Philippines, and a review of the mollusc culture techniques and research gaps in the Philippines.

WINDOW-PANE OYSTER

In 1909, Hornell reported that the window-pane oyster, *P. placenta,* is widely distributed but at present, it is only in India (Narasimham 1973) and the Philippines (Rosell 1979) that its occurrence and utilization have been documented. In the Philippines, it is extensively collected from the wild and can be fashioned into various shellcraft items which are exported. However, the dwindling supply of the *P. placenta* from the wild hinders the expansion of the industry in the Philippines. Therefore, there is an urgent need to properly manage this species. Research has been focused on stock assessment and development of hatchery and grow-out technology.

Induced Spawning

P. placenta has been successfully induced to spawn through water flow manipulation (Young 1980). The same method failed when repeated in 1989-1990. Limited success was obtained using other techniques such as temperature shock, salinity shock, addition of gametes, and overfeeding. Spawning techniques will be developed upon availability of spawners.

Hormonal induction of spawning will be conducted using serotonin, which has been shown to be effective in induced spawning of nine species of bivalves (Matsutani and Nomura 1982, Gibbons and Castagna 1984, Belda and del Norte 1988, Velez et al. 1990).

Broodstock Maturation

To offset the problem of seasonal availability of wild *P. placenta* spawners, an attempt was made to develop broodstock in tanks. Sexually immature *P. placenta* were given supplemental feeding of either the diatom *Isochrysis galbana* Parke, and the green alga *Tetraselmis tetrahele* (G.S. West) Butch, or their 1:1 combination at 100,000 cells per milliliter divided into 2 rations per day. Monthly histological examination shows a rapid gonad development in *P. placenta* fed the combination of *I. galbana* and *T. tetrahele,* attaining sexual maturity on the third month, a month ahead of those fed single algal species (Gallardo et al. 1992).

Transplantation

As an initial work towards the development of farming techniques for *P. placenta,* an experiment was done in a cove at SEAFDEC/AQD's Igang Marine Substation at Guimaras Island to test for transplantation and farming of *P. placenta,* with a mean shell height of 66 millimeters were stocked at a density of 100 individuals per square in a 3 x 1 meter area. Growth increment and survival rate after 6 months were 19 millimeter (specific growth rate = 0.15 millimeters per day) and 32%, respectively. Physico-chemical parameter ranges were salinity, 26-28 parts per thousand, temperature of 27-32°C, pH 6.2-7.4, and, 0.2-1.6 parts per million net photosynthesis. These results are comparable with published data on the growth of natural populations (Rosell 1979, 1984) and in laboratory conditions (Young 1980).

Evaluation and Restocking of Depleted *P. placenta* Beds

The bays of Oton, Tigbauan, and Guimbal municipalities in lloilo Province had been a natural bed of *P. placenta* until 1983. It is hypothesized that overharvesting, trawling, and possible change in the bio-physico-chemical characteristics of the area are the possible cause of the depletion. An evaluation of the area for restocking and repopulation has started, taking into consideration the type of substrate, quality of benthos and plankton, physico-chemical parameters, primary productivity of the water, and the growth and survival of restocked *P. placenta.* Data on the characteristics of the area were compared with the published data on the ecology of *P. placenta* (Rosell 1979).

SADDLE-SHAPED OYSTER

Studies on Reproductive Biology, Condition Index, and Proximate Composition

The saddle-shaped oyster *Placuna sella* (locally known as *"bay-ad")* is heavily exploited particularly from the bay of Banate, Iloilo Province, and nearby areas because of the high demand for its delicious meat. Concerned over its possible depletion just like *P. placenta* in some natural beds, researchers at SEAFDEC/AQD are conducting studies on its reproductive biology, variations in condition index, and proximate composition during reproductive cycle. The data gathered will provide information on its spawning season and the suitable time for commercial harvest.

GREEN MUSSEL AND SUPPER-SHAPED OYSTER

Socioeconomic Study of Oyster and Mussel Farming Practices in Western Visayas

This study, in collaboration with the International Center for Living Aquatic Resources Management (ICLARM) through the Asian Fisheries Social Science Research Network (AFSSRN), aims to: 1) determine the characteristics and social conditions of oyster and mussel farmers, 2) assess the farming methods and technology practiced in oyster and mussel culture 3) analyze the detailed input-output data of operations and the production performance indicators of efficiency in terms of resource utilization and rate of returns, and 4) determine the development potential, identify problems and constraints, and formulate appropriate management policies that would sustain the development and viability for the oyster and mussel industry.

It was initially found that 1,597 oyster and mussel farmers operate in the provinces of Aklan, Capiz, Iloilo, and Negros Occidental in central Philippines. Negros Occidental had the most number of oyster and mussel farmers and the most advanced culture technology. The culture methods used are broadcast, stake, raft, and hanging, with several modifications of these methods. In addition, the commonly used culture substrates are empty oyster shells, old rubber tires, bamboos, wood, and nipa petioles.

OTHER SPECIES

Review of the Culture Techniques and Research Gaps in the Philippines

An assessment of mollusc research in the Philippines was conducted to review the culture techniques and identify research gaps. The study indicated that there are 17 species under 10 genera of bivalves that are subject of research studies. These are the mussels *(Perna viridis* and *Modiolus metcalfei),* oysters

(Crassostrea iredalei, Placuna placenta, Pinctada margaritifera, and *P. maxima),* scallop *(Amusium pleuronectes),* angel-wing clam *(Pholas orientalis),* abalone *(Haliotis varia, H. asinina),* giant clams *(Tridacna maxima, T. squamosa, T. crocea, T. derasa, T. gigas, Hippopus hippopus,* and *H. porcellanus).* Those with extensive basic information are *C. iredalei, P. viridis,* and *P. placenta.* The first two species have developed culture technology. For *C. iredalei* and *P. viridis,* research gaps include mortality from spat to market size, percent fertility and survival of trocophore to spat stage, standard method of spatfall forecasting, effects of foulers and epibionts on growth rates, determination of productive level of water column, and hatchery technology for seed production.

CONCLUSION

Compared with other commodities such as prawns/shrimps, bivalves still have a lot of research areas to be worked on toward the development of culture techniques, especially for the window-pane oyster *P. placenta.* A number of research work have already been done on the slipper-shaped oyster and the green mussel. The on-going socio-economic study on oyster and mussel would evaluate the farming practices particularly in western Visayas and would provide insights in refinement and transfer of appropriate technology.

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SEAWEED: *GRACILARIA*

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ABSTRACT

This paper reviews the studies on *Gracilaria/Gracilariopsis* conducted from 1988 to 1991 by the Aquaculture Department, Southeast Asian Fisheries Development Center. It includes 114 species of macrobenthic algae collected in Panay, the nomenclature of *Gracilariopsis heteroclada* previously described as *Gracilaria* sp., and the biology, ecology, and farming systems of *Gracilariopsis.* Agar quality of the different species of *Gracilaria* and the effect of seasonal variation on the quality and quantity of agar produced from *Gracilariopsis heteroclada* were also studied.

INTRODUCTION

During the ADSEA '87, member countries of the Southeast Asian Fisheries Development Center (SEAFDEC) recommended *Gracilaria* as the number one priority for seaweed research in the following areas: 1) refinement of culture techniques, 2) basic biology, 3) product utilization, and 4) screening and characterization of natural products. The research activities (1988-1991) for *Gracilaria* at SEAFDEC Aquaculture Department (AQD) included: 1) inventory and assessment of biomass production, 2) development of seed production techniques, 3) biology-ecology of natural stock, 4) development or adaptation of techniques for pond culture and coastal farming, and 5) characterization of agar. Studies on product utilization were not conducted due to limited senior staff in the Seaweed Project, instead, an inventory of the macrobenthic algae of Panay Island, western Visayas, central Philippines was conducted to provide basic information on the taxonomy and distribution of available seaweeds.

RESEARCH ACCOMPLISHMENTS

Taxonomy

Inventory of Marine Macrobenthic Algae. From 1988-1989, marine macrobenthic algae were collected to determine the marine algal resources of Panay Is. A total of 114 species were identified which include 38 *Chlorophyceae,* 21 *Phaeophyceae,* and 55 *Rhodophyceae.* To date, there are 37 species considered as new record for Panay.

Nomenclature of Gracilaria sp. Gracilaria sp. *(=Gracilaria* sp. 2 in Trono et al. 1981) in earlier studies of SEAFDEC/ AQD is referred to in this paper as *Gracilariopsis heteroclada* (Zhang et Xia) Zhang et Xia (basionym: *Gracilaria heteroclada* Zhang et Xia) (Personal Communication).

Genera included in the Order *Gracilariales* found in western Visayas were *Gracilaria arcuata Zanardini, G. blodgettii Harvey, G. coronopifolia J. Agardh, G. eucheumoides Harvey, G. salicornia* (C. Agardh) Dawson, *G. 'verrucosa'* (Hudson) *Papenfuss, Gracilariopsis heteroclada* (Zhang et Xia) Zhang et Xia.

Biological Study of *Gracilariopsis*

Reproductive States. The reproductive states of *G. heteroclada* were studied from wild stocks gathered in Jaro district of Iloilo City. Presence of carposporophytes and tetrasporophytes was high in January (48%) and May (64%), respectively. Percentage occurrence of carposporophytes and tetrasporophytes was not significantly correlated with water temperature, salinity, and turbidity.

Ecology

Assessment of a Gracilariopsis Natural Bed. The standing crop of *G. heteroclada* natural bed at Jaro and Leganes district of Iloilo, Ivisan district of Capiz, and Batan district of Aklan was assessed monthly (de Castro et al. 1991). There was a marked seasonality in biomass of *G. heteroclada* like species of *Gracilaria* (Black and Fonck 1981, Trono and Azanza-Corrales 1981) and this differs according to locations. Correlation analysis shows an inverse relationship between biomass and rainfall in Leganes, Ivisan, and Batan.

Environmental Parameters. Temperature had no effect on the biomass of *G. heteroclada* in Leganes, Ivisan, and Batan biomass was negatively correlated with salinity in Leganes and Batan but not in Ivisan; no relationship existed between biomass and pH in Leganes, Ivisan, and Batan. On the other hand, significant differences between the monthly biomass of *G. heteroclada* were observed in Jaro. No correlation was detected between biomass and the different environmental factors (water temperature, salinity, turbidity, water movement, and the nutrient levels of water) at the natural bed of *Gracilariopsis* at Jaro.

Salinity Tolerance. *G. heteroclada* when reared at different levels of salinity under ambient conditions shows that it can tolerate low levels of salinity. However, plants reared in lower (5-15 ppt) and higher (35 ppt) salinities are brittle and brownish with rough surface and short branchlets. Plants grown at 20-30 parts per thousand resembled the natural characteristics of wild plants which are succulent, purplish, bushy, and healthy. Apparently, plants at 25 ppt grow best. *G. heteroclada* show similar characteristics as other euryhaline species. This preliminary findings suggest that this species can be best cultivated in seawater to brackishwater areas.

Management of a Natural Bed

Regeneration Capacity. The amount of harvest left after the first cropping is important in determining the amount of biomass available for the next cropping season. Among the 4 levels of harvest (25, 50, 75, and 100%), 75% provides the appropriate amount of "seeds" for the next cropping season. The amount of biomass to be harvested during each harvest regime should not exceed the amount of biomass available for cropping.

Harvesting Tools. Among some harvesting tools (araña, rake, scissors, or bare hands) tested on the regeneration capacity of *G. heteroclada,* araña is ineffective in areas where *Gracilariopsis* were exposed during the lowest tide. However, the results of Santelices et al. (1984) in Chile show otherwise. Earlier reports have shown that raking seaweeds brings excessive disturbance on the substrate and to the population (Luxton 1981).

Farming Systems

Cage Culture. Field culture of *G. heteroclada* using vegetative fragments inserted between braids of ropes suspended vertically inside a floating cage showed significant differences in growth rate and monthly yield (Hurtado-Ponce 1990). Any of the 3 spacing intervals may give high yield. Both growth and yield were minimum in December at all spacing intervals but maximum in April at l0 and 15 centimeters and in February at 20 centimeters. Approximately, 1.4 tons (dry) per hectare per year was produced from this system.

The specific growth rate of *G. heteroclada* grown at 25, 50, and 100 cm below the water surface with *Lates calcarifer* fingerlings in floating cages was found to be influenced by the of presence of sea bass, water depth, and month of culture (Hurtado-Ponce 1992). Growth rate of *Gracilariopsis* was highest near the water surface and lowest at 100 centimeters. High survival rate (92-100%) and production (6.8-% kilogram/cage) of *L. calcarifer* were obtained. The polyculture of *G. heteroclada* and *L. calcarifer* was encouraging.

Statistical analysis showed significant differences in specific growth rate and net production rate ($P<0.05$) among the four stocking densities (400,500,600 and 700 grams per square meter) tested in growing *G. heteroclada* in hapa nets installed to a floating cage (Guanzon and de Castro 1992). Specific growth rate and net production rate were found to be significantly different within a 12-month cultivation period. Specific growth rates and net production rates were higher during the dry season.

Pond Culture. Higher growth rate (2.5% per day) and net production rate (8.8 g/m/day) were obtained at lower stocking density (500 g /m^2) than at higher stocking density (600 and 700 g/m^2) when *G. heteroclada* was cultured in hapa nets inside a pond (de Castro, unpublished results). Production was higher during the dry season. Salinity was positively correlated while total rainfall was negatively correlated with specific growth rate and net production rate ($P < 0.05$); temperature and pH had no effect on these parameters ($P > 0.05$).

Bottom Line Cultivation. Adapting the fixed bottom line technique (Doty 1973) of cultivating *G. heteroclada,* about 12-92 tons dry weight/ha/year is produced from this method. These values are relatively high compared with the production obtained in ponds (Chiang 1981, Shang 1976) but almost identical with the reports of Hanisak (1981) and Ryther et al. (1979) in tanks.

Agar Characterization

Strain *Selection.* Agar from *G. blodgettii, G. coronopifolia,* G. *eucheumoides, G. 'verrucosa',* and *Gracilariopsis heteroclada* were screened quantitatively and qualitatively. Results showed that *G. blodgettii, G. 'verrucosa',* and *G. heteroclada* are potential sources of food agar based on their physical properties. Refinement of the extraction methodology is necessary to improve the agar qualities from these species.

Seasonal Variation of Agar Quality and Quantity. Yield, gel strength, and melting and gelling temperature of *G. heteroclada* collected in Jaro varied according to months (Luhan 1992). Gel strength of *G. heteroclada* was negatively correlated with percent dry yield but not with the different environmental factors. The gel strength of agar also differed significantly with month of sample collection.

CONCLUSIONS AND RECOMMENDATIONS

Cage culture (monoculture and polyculture) and line cultivation of *Gracilariopsis heteroclada* are possible. *G. heteroclada* is a good source of food agar and possibly bacteriological agar.

The following are recommended research areas for future work: 1) seed development techniques for outplanting, 2) mono- and polyculture of *G. heteroclada* in ponds, 3) refinement of extraction methodologies, 4) utilization of raw material and agar in aquaculture, and 5) pharmacological studies on *Gracilaria/Gracilariopsis* species.

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OVERVIEW OF AQUACULTURE DEVELOPMENT IN SOUTHEAST ASIA

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ABSTRACT

The nine countries in Southeast Asia occupy a land area of 1.85% with a population of 7.4% in the world. In 1991, these countries had a total fisheries production of 10.2 million tons or 10.5% of the world total of 96.9 million tons. In aquaculture in 1990, world total production attained 15.3 million tons (15.7% of total world fisheries production) while the Southeast Asian countries produced 1.7 million tons (11 % of total world aquaculture production). The total fisheries production in Southeast Asia which is mainly capture fisheries has continued to increase gradually by about 3.3% from 1986 to 1990 while aquaculture production has been increasing at the rate of over 8.4% during this period.

The major areas for aquaculture in Southeast Asia include inland freshwaters, brackishwaters, and marine waters. Various systems exist in the region including ponds, pens and cages, delimited or fenced open water areas, and culture integrated with other production activities. Highest potential is in Seafarming while ranching is a recent innovation. The species being cultured in the region consist of about 50 fishes, 10 crustaceans, 10 molluscs, 5 seaweeds, and 5 miscellaneous aquatic vertebrates.

Aquaculture will increasingly supply food and industrial products considering the worldwide levelling off of capture fisheries production. Southeast Asia has the potential to contribute substantially to this need. Support for the industry inspite of this need is inadequate to meet its technical, economic, and management problems. A sound technological base through research and training and extension needs to be pursued vigorously.

INTRODUCTION

Southeast Asia consists of nine closely situated countries, namely: Brunei Darussalam, Indonesia, Kampuchea, Laos, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam. Collectively these countries occupy 1.85% of the world land area but they have 7.4% of the world population. These countries are very diverse in their physical, social, and economic conditions (ADB 1992, Table 1).

Fisheries in these countries is important. The total fisheries production in the region has grown slowly from 8.9 to 10.2 million tons or a growth of 3.87% annually (Table 2) in the recent five years (1985-1989). This regional production constitutes about 9.7% of world total production (FAO 1991). Aquaculture, however, is widespread and varied and has been growing more rapidly from 720,000 tons in 1980 to 1.2 million tons in 1986 and 1.7 million tons in 1990 or an annual growth of 8.4%. This regional aquaculture production represents 11.0% of the total world aquaculture production (FAO 1992, Table 3). Fish consumption is relatively high but varies lowest at 6 kilograms/person/year in Laos to 46 kilograms/person/year in Malaysia (Rabanal 1988). The long coastline of these countries and their extensive inland and marine shelf waters contribute in making fisheries and especially aquaculture a vital factor in their economies (Table 4).

SITES AND SPECIES USED FOR AQUACULTURE

Environments

The environments used for aquaculture in Southeast Asia are varied. These may be classified by: 1) salinity of water supply, 2) rate of water renewal, and 3) species used.

Salinity. According to salinity, sites used are either freshwater, brackishwater, or marine water. Inland freshwater aquaculture is probably the oldest site used and is very well distributed. Due to pressure of population and urbanization, however, this type of aquaculture has levelled off and is even declining is some areas.

Brackishwater aquaculture has a long history in the region. Estuarine tidal areas and swamps are usually developed for this purpose. Indigenous technology has been available, but its advance has been slow. Recently, with available international market for penaeid shrimps, brackishwater aquaculture technology has advanced.

Seafarming or mariculture has grown in the region but its full potential has not been attained (Rabanal, 1986).

Rate of Water Renewal. Aquaculture environments can vary from stagnant such as in freshwater ponds and semi-stagnant as in brackishwater ponds that are constantly refreshed with new water, or by active running water supply. The latter case is exemplified by the running water carp ponds used in Indonesia.

Table 1. Vital socio-economic statistics of Southeast Asian countries, 1991

Country	Area (km^2)	Population (million)	Population density per km^2	Population growth (%)	Per capita GNP 1990 (US$)
Brunei Darussalam	5,765	0.221**	38	3.3	22,150*
Indonesia	1,919,443	177.6*"	93	2.3	550
Kampuchea	181,035	8.2***	45	NA	NA
Laos	236,800	4.3	18	NA	170
Malaysia	329,749	18.2	55	2.8	2,320
Philippines	300,000	62.1	207	2.78	760
Singapore	618	2.8	4,531	1.5	12,310
Thailand	542,373	56.9	105	2.5	1,420
Viet Nam	329,556	67.7	205	2.1	189
Total for SEA	3,845,339	398.021			
World Total	207,495,423	5,385.3			
Percent SEA on world production	1.85	7.4			

*1988; **1989; ***1990; NA - Data not available
Note: Above data were taken mainly from Asian Development Bank (1992)

Table 2. Total fisheries production in Southeast Asia in recent years, 1987-1991

Country	1987 (tons)	1988 (tons)	1989 (tons)	1990 (tons)	1991 (tons)
Brunei Darussalam	3,915	2,041	2,318	3,350	1,652
Indonesia	2,583,874	2,789,100	2,948,406	3,043,183	3,186,000
Kampuchea	79,571	82,200	76,550	105,000	111,100
Laos	20,000	20,000	20,000	20,000	20,000
Malaysia	619,332	612,421	609,648	603,981	620,000
Philippines	1,988,718	2,010,363	2,098,787	2,208,823	2,311,797
Singapore	16,655	15,240	12,615	13,316	13,054
Thailand	2,799,091	2,642,059	2,699,835	2,786,383	3,065,170
Viet Nam	871,404	874,000	868,000	850,000	877,000
Total for SEA	8,962,560	9,047,424	9,336,159	9,633,036	10,205,763
World Total	94,378,600	99,016,100	100,208,300	97,433,500	96,925,900
Percent SEA production on world production	9.5	9.1	9.4	9.9	10.5

Source: FAO, 1991.

Table 3. Aquaculture production in Southeast Asia in recent years, 1986-1990

Country	1986 (tons)	1987 (tons)	1988 (tons)	1989 (tons)	1990 (tons)
Brunei Darussalam	0	2	2	2	2
Indonesia	410,554	456,727	490,091	501,458	558,855
Kampuchea	2,340	2,640	4,741	6,282	6,080
Laos	2,500	2,500	2,500	2,500	2,500
Malaysia	51,433	46,937	46,910	54,833	47,876
Philippines	470,923	560,970	599,564	629,325	672,316
Singapore	1,330	1,855	1,969	1,965	1,857
Thailand	128,417	174,492	219,101	260,181	253,326
Viet Nam	135,500	145,300	136,700	149,700	155,000
Total for SEA	1,202,997	1,391,433	1,511,478	1,606,246	1,697,812
World Total	12,206,738	13,179,669	14,556,515	14,419,829	15,331,822
Percent SEA production on world production	10.0	10.6	10.4	11.1	11.1

Source: FAO, 1992.

Table 4. Fisheries and related statistics of Southeast Asian countries, 1990

Country	Total fisheries production (tons)	Aquaculture production (tons)	Annual per capita fish consumption (kg)	Length of coastline (km)	Water area Inland (km^2)	Water area Marine (km^2)
Brunei Darussalam	2,350	2	40	161	803	NA
Indonesia	3,043,183	558,855	16	36,384	NA	775,000
Kampuchea	105,000	6,080	24	435	NA	40,000
Laos	20,000	2,500	6	-	NA	
Malaysia	603,981	47,876	46	4,405	15,797	418,000
Philippines	2,208,823	672,316	40	17,460	8,129	185,000
Singapore	13,318	1,857	41	138	NA	966
Thailand	2,786,383	253,326	22	2,614	45,450	305,000
Viet Nam	850,000	155,700	12	NA	NA	NA
Total for SEA	9,633,038	1,697,812				
Word Total	97,433,500	15,331,822				
Percent SEA on world total	10.0	11.1				

Percent SEA aquaculture production on SEA total fisheries production	17.6
Percent world aquaculture production on world total fisheries production	15.7

Source: FAO, 1991
FAO, 1992
Rabanal, 1988

Aquaculture in open waters (e.g. for mollusc and seaweed culture, and cage and pen culture) can be considered semi-stagnant as they are subjected to constant renewal through slow natural water movements.

Species Used. The major groups of farmed aquatic organisms are: 1) fish, 2) crustaceans, 3) molluscs, 4) seaweeds and other aquatic plants, and 5) miscellaneous aquatic vertebrates and invertebrates. About 250 species of aquatic organisms are farmed worldwide of which about 80 are cultured in the Southeast Asian region (Table 5).

Fishes compose the major taxonomic group of cultured aquatic organisms. Two major types are farmed, namely: freshwater and marine fishes. The saltwater forms are either cultured in brackish or in marine waters. In Southeast Asia, some of 50 species out of some 150 species cultured worldwide are probably farmed (Table 5). The region also produces 10.6% of the world production in this group (Table 6). The freshwater species farmed in SEA are about 35 while marine species number about 15. Of the freshwater species, the cyprinids or carps are dominant and widely distributed. Common carp and the Chinese and Indian major carps are more important as well as smaller cyprinids like the barbs. The tilapias, although introduced species, have become rapidly dominant in freshwater fish production in the region. Various catfishes and the gouramis are also important.

The marine species is dominated by milkfish while mullets and rabbitfish are of minor importance. The culture of carnivorous species of high market value such as sea bass, groupers, and to a lesser extent snappers, breams and jacks has recently grown in importance.

The cultured crustaceans in Southeast Asia are mainly marine forms. There is only one outstanding freshwater species cultured, the giant river prawn *(Macrobrachium rosenbergii).* Penaeid shrimps compose the major farmed crustaceans in the region resulting from the large international market that has developed in Japan, North America, and western Europe though the market is now dwindling. The farming of this group of species including seed production from hatcheries has now been well satisfied. Culture of other species which were previously just being gathered from the wild have been started. These are the mangrove crab *(Scylla serrata),* swimming crab *(Portunus* spp.), and the spiny lobster *(Panulirus).* Some 10 crustaceans are cultured in Southeast Asia while 35 species are cultured worldwide (Table 5). The region produces about 40% of world production in this group (Table 6). If the production of mainland China and Taiwan are included, the area produces over 70% of world production of farmed crustaceans.

Some 12 species of molluscs are cultured in Southeast Asia while there are 50 species farmed worldwide (Table 5). Although mollusc culture production is important to specific local economies, it has suffered setbacks in the international market and lately by environmental problem such as the red tide. Mussels and oysters suffer from contamination of *E. coli* and have been unacceptable for export and even in some local areas. Occurrence of red tide in specific sites in Sabah (Malaysia), the Philippines, and perhaps elsewhere in the region is another problem. Rapid pollution of many coastal waters also poses a problem

Table 5. Aquaculture production in Southeast Asia, by kind, 1990

Country	Finfish (tons)	Crustaceans (tons)	Molluscs (tons)	Miscellaneous invertebrates	Miscellaneous vertebrates	Seaweeds and other aquatic plants	Total (tons)
Brunei Darussalam	2	NA	NA	NA	NA	NA	2
Indonesia	381,485	97,370	NA	NA	NA	80,000	558,855
Kampuchea	6,080	NA	NA	NA	NA	NA	6,080
Laos	2,500	NA	NA	NA	NA		2,500
Malaysia	11,757	2,221	40,896	NA	NA	NA	54,874
Philippines	282,119	49,283	29,222	NA	NA	268,701	629,325
Singapore	433	303	1,229	NA	NA	NA	1,965
Thailand	93,060	72,803	51,399	NA	2	NA	217,264
Viet Nam	14,500	NA	NA	NA	NA	1,700	146,700
Total for SEA	882,245	221,980	122,746		2	350,401	1,617,565
World Total	7,322,699	613,338	3,120,401	32,695	1,227	2,988,242	14,078,602
Percent SEA production on world production	12.0	31.9	3.9	0.2	11.7	11.0	

NA, data not available. -, amount negligible or practice not applicable.

Table 6. Species cultured in Southeast Asia

	Scientific name	Common English name	Countries where cultured*
I.	Finfish		
1.	*Cyprinus carpio*	Common carp	B, I, K, L, M, P, T, V
2.	*Hypophthalmichthys nobilis*	Bighead carp	B, K, L, M, P, T
3.	*H. molitrix*	Silver carp	B, K, L, M, P, T
4.	*Ctenophatyngodon idella*	Grass carp	B, K, L, M, P, T
5.	*Cirrhinus molitorella*	Mud carp	P, S
6.	*Labeo rohita*	Rohu	K, P, T
7.	*Labeo* spp.	Rhinofishes	K
8.	*Carassius carassius*	Crucian carp	I, S
9.	C. *auratus*	Edible goldfish	I, S
10.	*Puntius gonionotus*	Thai silver barb	B, I, M, P, T
11.	*P. javanicus*	Java barb	I, K
12.	*Puntius* spp.	Asian barbs	I, K
13.	*Leptobarbus hoeveni*	Hoven's carp	B, K, M, T
14.	*Probarbus jullieni*	Jullieni carp	T
15.	*Helostoma temmincki*	Kissing gourami	I
16.	*OsteocMlus hasselti*	Nilem carp	I
17.	*Notopterus* spp.	Knife fishes	I, T
18.	*Oreochromis mossambicus*	Mozambic tilapia	B, I, K, L, M, P, T
19.	*O. niloticus*	Nile tilapia	I, L, M, P, T
20.	*Oreochromis* spp.	Tilapias	M, P
21.	*Clarias batrachus*	Walking catfish	I, L, P, T
22.	*C. macrocephalus*	Walking catfish	I, L, P, T
23.	*Pangasius pangasius*	Pangas catfish	M, T
24.	*P. sutchi*	Pangasius catfish	K, T
25.	*Channa striatus*	Striped snakehead	L, P, T
26.	C. *micropeltes*	Indonesian snakehead	L, K, T
27.	*Osphronemus goramy*	Giant gourami	I, P, T
28.	*Trichogaster pectoralis*	Snakeskin gourami	I, K, L, M, P, T
29.	*Trichogaster* spp.	Snakeskin gouramis	I, T
30.	*Anguilla* spp.	River eels	I

(next page)

	Scientific name	Common English name	Countries where cultured*
31.	*Oxyeleotris marmoratus*	Marble goby	M, T
32.	*Anabas testudineus*	Climbing perch	T
33.	*Fluta alba*	Freshwater eel	T
34.	*Misgusnus anguillicaudatus*	Loach	P
35.	*Chanos chanos*	Milkfish	I, P, T
36.	*Lates calcarifer*	Giant sea perch or sea bass	B, I, M, S, T
37.	*Epinephelus tauvina*	Greasy grouper	M, S, T
38.	*Epinephelus* spp.	Groupers	M, S, T
39.	*Mugil cephalus*	Gray mullet	I, T
40.	*Mugil* spp.	Mullets	I, T
41.	*Siganus guttatus*	Rabbitfish	P, S
42.	*S. canaliculatus*	Rabbitfish	P, S
43.	*Siganus* spp.	Rabbitfishes	P, S
44.	*Lutjanus argentimaculatus*	Mangrove red snapper	M, S
45.	*Lutjanus* spp.	Snappers	M, S
46.	*Chrysophrys* major	Porgy or seabream	M, S
47.	*Sparidae*	Porgy or seabream	M, S
48.	*Caranx* spp.	Jacks	I, S
II.	Crustaceans		
1.	*Macrobrachium rosenbergii*	Giant freshwater prawn	B, I, M, T
2.	*Penaeus monodon*	Jumbo tiger shrimp	I, M, P, T, V
3.	*P. indicus*	Indian white shrimp	P
4.	*P. merguiensis*	Banana shrimp	I, M, P, S, T, V
5.	*P. japonicus*	Kuruma shrimp	S
6.	*Penaeus* spp.	Marine shrimps	S, T
7.	*Metapenaeus* spp.	*Metapenaeus* shrimps	I, P, T, V
8.	*Scylla serrata*	Mangrove crab or mud crab	I, M, P, S, T
9.	*Portunus* spp.	Swimming crabs	I
10.	*Panulirus* spp.	Spiny lobster	S.
III.	Molluscs		
1.	*Mytilus smaragdinus*	Green mussel	M, P, S, T
2.	*Perna viridis*	Green mussel	S, G
3.	*Crassostrea iredalei*	Slipper oyster	P

(next page)

	Scientific name	Common English name	Countries where cultured*
4.	*Crassostrea* spp.	Cupped oysters	T
5.	*Anadara granosa*	Blood cockle	M,T
6.	*Modiolus* spp.	Horse mussels	T
7.	*Paphia* spp.	Short neck clams	T
8.	*Meretrix* lusoria	Japanese head clam	T
9.	*Tridacnidae*	Giant clams	I,P,T
10.	*Placuna placenta*	Window pane oyster	P
11.	*Pinctada* spp.	Pearl oysters	I,P,T
12.	*Pteria penguin*	Wing shell	P
IV.	Seaweeds and other aquatic plants		
1.	*Kappaphycus alvarezii*	*Kappa carragenous* seaweed	I,M,P
2.	*Eucheuma striatum*	Iota/beta carrageenous seaweed	I,M,P
3.	*E. denticulatum*	*Euchema* carrageenous seaweed	I,M,P
4.	*Caulerpa lentillifera*	Edible green seaweed	P
5.	*Caulerpa* spp.	Edible green seaweeds	P
6.	*Gracilaria verrucosa*	*Gracilaria* agar seaweed	V
7.	*Gracilaria* spp.	*Gracilaria* agar seaweeds	M,P,T,V
8.	Algae	Algae	I, M, P
V.	Miscellaneous aquatic invertebrates and vertebrates		
1.	*Rana* spp.	Frogs	I, T
2.	*Tryonix* spp.	Freshwater turtles	T
3.	*Testudinata*	Turtles	T
4.	*Crocodilus porosus*	Crocodiles	P,T
5.	*Crocodylus siamensis*	Thai crocodile	T

Source: Rabanal, 1988 (updated). Above list is what is known at present, it may be incomplete and may change in the future.

* B - Brunei Darussalam, I - Indonesia, K - Kampuchea, L - Laos, M • Malaysia, P - Philippines, S - Singapore, T - Thailand, V - Viet Nam

for mollusc culture. Industrial crop species such as pearl oyster, window pane oyster, and angel wing clam which used to be gathered from the wild are now depleted while the culture technology is not yet fully established.

Due to the above circumstances the Southeast Asian contribution to world farmed mollusc production is very meager or only about 0.5% of world production inspite of the large potential sites for culture and the presence of cultivable species (Table 6).

Seaweeds and other aquatic plants. Seaweeds used for food and industry have been gathered from natural waters in Southeast Asian countries for a long time. Recently, due to growing scarcity of natural stocks, seaweed culture was initiated in some Southeast Asian countries. The Philippines, Indonesia, and Viet Nam have reported commercial production of this group. About eight species may be in cultivation although perhaps only five belonging to two groups, the industrial crop and the food crop may be of commercial importance. About 10 species are farmed commercially worldwide (Table 6).

Southeast Asia produced about 11% of world farmed seaweeds in 1990, but the potential for much higher production exists in the region. Rapid and big fluctuation in price of the commodity has not contributed to a well planned production program in the region. The region continues to be one of the major producers of raw material while the main bulk of processing is done in developed countries outside the region.

Miscellaneous Aquatic Invertebrates and Vertebrates. Some five species of miscellaneous aquatic vertebrates are farmed in the region. There are no miscellaneous invertebrates of consequential amount cultured (Table 5). In other areas of the world sea squirts or tunicates, sea urchin, sea cucumbers, and sponges have started to be farmed. Even the vertebrates under cultivation in Southeast Asia are treated as novelties and perhaps not fully commercialized as economic venture. These include frogs, turtles, and crocodiles. There are, however, some potential and opportunities for the culture of this group of species in the region.

AQUAFARMING SYSTEMS AND PRODUCTION

Various aquaculture systems are now in existence in the region. These are 1) ponds or impoundments, 2) cages and pens, 3) open waters (marked or fenced), 4) aquafarming integrated with other production systems, and 5) ranching. These systems may be differently managed resulting in different levels of productivity.

Ponds or Impoundments

Ponds or impoundments compose the most common system prevailing in Southeast Asia. This system can be situated inland or along the coast so that these are usually land-based. It is used to culture mainly fish and crustaceans and can be susceptible to management intensification. Ponds are used for the culture of most fishes including carps, tilapias, catfishes, and gouramis as well as milkfish, mullets, and sea bass. It is also the major system in the culture of shrimps and prawns.

Cages and Pens

Cages and pens came after the ponds. Their easy management and the relative low cost and economy in the use of available space, have made them more popular. They are used in a wide range of environments from reservoirs, lakes, rivers, and coastal coves or bays where suitable. Fishes in either fresh or saltwater are usually farmed but lately penaeid shrimps and the mangrove crab have been used.

Marked or Fenced Open Waters

To culture molluscs and seaweeds, marked or fenced open waters are usually used. Various materials are usually used to provide anchorage for the cultured organisms (e.g. wood or bamboo poles, fiber ropes or twines, metal wire, and nets and nettings, with or without floats and weights).

Integrated Aquafarming

Integrated fish farming has a long tradition in the region but its use has been fluctuating. Examples of these practices are rice-fish farming, fish farming integrated with animal husbandry, and culture of certain shellfish with seaweed. There seems to be lack of standardized technology for these practices so that there is need for training and extension to disseminate their usage.

Ranching

Ranching is a recent innovation. It is a system where substantial stocks of farmable aquatic organisms are released in their natural habitat where they can feed or graze and grow so that these can subsequently be harvested by the normal capture methods (Baluyot 1989). In many regions of the world this practice has become successful (e.g. salmon, kuruma shrimp, and abalone), but its practice is still very limited in Southeast Asia. Identification of suitable species and the appropriate sites will be required.

Intensity of Culture and Productivity

Culture systems are extensive, semi-intensive, or intensive. At the lower and upper extremes, the traditional system (lowest level) and the hyper intensive system (highest level).

Various criteria for intensification are based on: 1) stocking rate of culture organism, 2) amount of operational inputs (fertilizers, feeds), 3) amount and rate of water conditioning or renewal, 4) degree of sophistication of physical infrastructures (engineering), and 5) availability of technology of culture including trained managers, technicians, and skilled labor. In all these levels of management, there is an upper limit beyond which further intensification can be harmful. For instance if the stocking rate is increased and the feeding rate and the aeration rate of a pond system are also raised, the production will continue to increase until it levels off. However, even before the highest point is reached the pond environment should be constantly monitored for any adverse environmental effects that may have been building up. Intensification can then be stopped at a suitable level. The hyper intensive level of management is designed to overcome the possible adverse environmental effects of further intensification such as the production of structures to eliminate metabolites-. However, the effects to neighboring areas of such action should likewise be considered and the economics of unlimited intensification should always be taken into account.

CONSTRAINTS AND RECOMMENDATIONS

Constraints

There are three types of constraints: technical, socio-economic, and administrative. The technical constraints include:

a. Lack of knowledge of the biology of cultured species
b. Inadequate supply of seedstocks for culture
c. Undeveloped technology of culture
d. Post harvest problems including processing, refrigeration, and handling
e. Deterioration of environmental quality of aquaculture sites
f. Lack of trained managers, technicians, and skilled laborers
g. Increasing losses due to advent of diseases and other causes of mortality

The socio-economic constraints are:

a. High cost of capital investment required to establish and operate projects
b. Lack or poor market demand for product
c. High cost of production due to expensive inputs
d. Lack of preferential credit to support industry
e. Unforseen losses brought about by the occurrence of natural calamities like typhoons, earthquakes, volcanic eruptions, etc.

The administrative or management constraints are:

a. Lack of needed infrastructures in aquaculture areas
b. Weak support to curb deleterious effects of environmental deterioration
c. Inadequate government support in terms of policy legal and institutional aspects, and credit

Recommendations

1. Promote cooperative programs, among institutions involved in aquaculture either interregional, regional, or national.

2. As the industry problems are extensive, priorities have to be set so that the most pressing problems could be tackled first.

3. More funding support will be required for research development, extension, and training in aquaculture, in particular with recent urgency on Seafarming and ranching.

4. Genetic studies and breeding should be pursued more aggressively to maintain and/or improve quality of cultured stocks.

5. Basic studies of immediate urgency on the technology of culture and on the biology of cultured species should be identified and pursued vigorously.

6. Market demand and margin of profit usually dictate the pace of development of any specific type of aquafarming, hence concerted studies should be made on the economics of production and product development of aquaculture commodities.

7. As the need for formulated feeds in aquaculture has increased considerably, adequate research will be required on the biology and nutrition of the different farmed species and the formulation of feeds from indigenous sources.

8. Many areas in the region are prone to natural disasters, therefore, the engineering design and structures of aquaculture industries should be geared to reduce to the minimum the dangers from these calamities.

9. Developed countries which are beneficiaries for a good number of aquatic species cultured in developing countries should contribute greater support for research in aquaculture in the region.

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BIOTECHNOLOGICAL RESEARCHES AT THE PREFECTURAL FISHERIES EXPERIMENTAL STATION IN JAPAN

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ABSTRACT

Biotechnological studies have been conducted in 46 Prefectural Experimental Stations in Japan in 1991. In 41 of these, research focused on chromosome set manipulation including triploidy for sterilization and gynogenesis for sex control. Practical application of biotechnology for culture of each species is the main interest because each prefecture has its own project for promoting the local fisheries industry. Therefore, the commodities being studied are of commercial importance comprising of about 40 species.

The culture production of Japan in 1988 totaled 1,426,000 tons, 95% of which consisted of 10 species. Biotechnology is not widely used since most seeds are not from hatcheries, but from the wild. Recently, however, promising results on the study of sex determination mechanism in the Japanese flounder have been adopted for actual seed production. This has attracted attention as an approach to mass production of all-female seedlings.

INTRODUCTION

In Japan, biotechnological studies are carried out on various species of fish, shellfish, and algae. Most of them are not practical but basic research in aquaculture.

In the Prefectural Fisheries Experimental Stations, biotechnological studies focused on chromosome set manipulation, including triploidy for sterilization

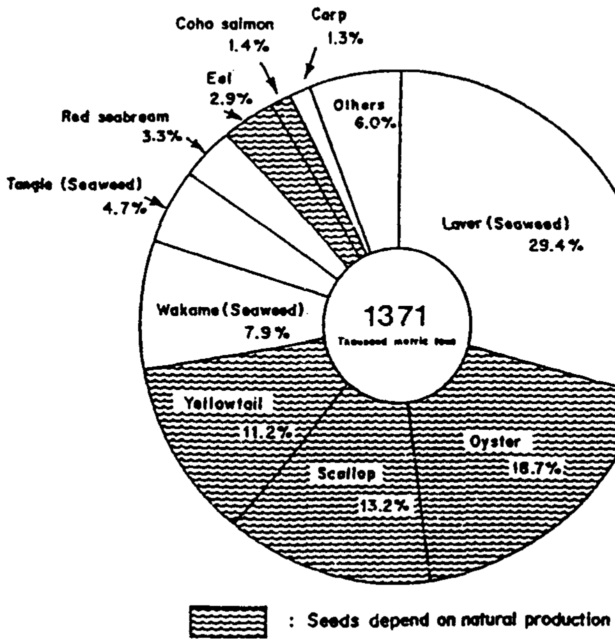

Fig. 1. Culture production of Japan in 1989

and gynogenesis for selective breeding and sex control. The stations' main concern is the practical application of biotechnology for aquaculture of each species because each prefecture has its own projects for promoting the local fisheries industry. As many as 40 species are being studied.

The culture production of Japan in 1989 totaled 1,370,600 tons, 94% consisted of 10 species (laver, oyster, scallop, yellowtail, wakame seaweed, tangle, red sea bream, eel, coho salmon, and carp in this order). Biotechnology has been rarely used in many of these commodities because most seeds are from the wild (Fig. 1). Recently, however, promising results were obtained on sex determination and sex differentiation of the Japanese flounder, *Paralichthys olivaceus* and these have been used for actual seed production. This has attracted attention because it is an approach to mass production of all-female seedlings (Fig. 2).

TRIPLOIDY

One of the most important requirements for aquaculture is constant production and supply of seedlings. This requires healthy and mature animals. However, culturists whose primary consideration is attaining marketable size in a short culture period may find maturation an undesirable process because

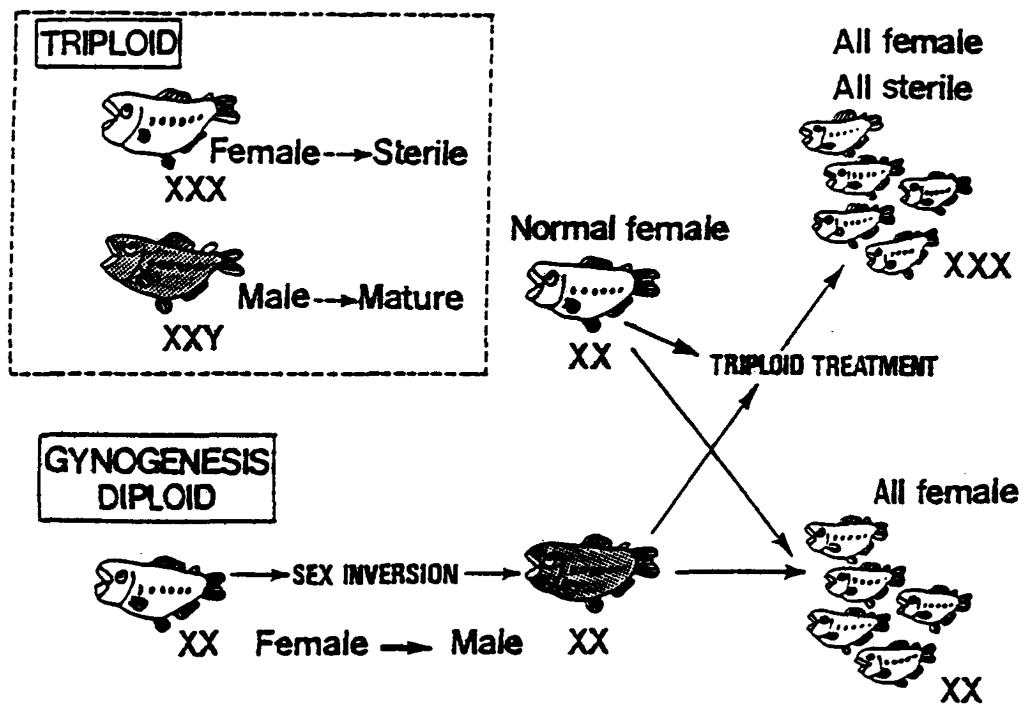

Fig. 2. All-female production systems by using chromosome set manipulation in rainbow trout

it retards growth and may cause onset of diseases. Studies on triploidy are being conducted to produce sterile seedlings. Triploidy has been studied in 41 Prefectural Fisheries Experimental Stations, using 20 species of fish *(Paralichthys olivaceus, Limanda yokohamae, Pagrus major, Acanthopagrus schlegeli, Oplenathus fasciatus, Fugu rubripes, Oncorhynchus kisutch, O. masou, O. nerka, O. rhodurus, O. mykiss, Salvelinus leucomaenis, Cyprinus carpio, Plecoglossus altivelis, Carassius buevgeri grandocutis, C. cuvieri, Misgurnus anguillicaudatus, Oreochromis mossambicus, Gnathopogon caerulescens,* and *Odontheste bonariensis)* and 4 species of shellfish *(Haliotis discus, Crassostrea gigas, Pinctada fucata martensii,* and *Chlamys nobilis).*

A triploid can be induced by inhibition of meiosis in eggs. Retention of the second polar body, which is normally extruded from the egg, may produce the embryo with three sets of genome consisting of female, male, and second polar nucleic chromosome. If eggs are stimulated after insemination by temperature or pressure, meiosis is inhibited, producing triploid rather easily.

Studies have been done to find out whether or not the triploid is sterile among many species. It is now clear that the extent of sterility in triploids varies among species, and, in addition, among sexes of the same species. In the triploids of rainbow trout and Japanese flounder the female triploid (XXX) is sterile but the male triploid (XXY) can mature (Tabata 1991a). Furthermore, the scallop, *C. nobilis,* is sterile in both sexes (Komaru and Wada 1989), while the Japanese pearl oyster, *P. fucata martensii,* matures in both female and male (Komaru and Wada 1990).

It is expected that growth rate of the triploid would be higher than that of diploid, but no studies have been done to confirm this.

Production of a triploid by mating a tetraploid with a diploid has not been well established in Japan because it is quite difficult to produce tetraploid.

GYNOGENESIS

In most fish species cultured in Japan, males mature earlier than females- Females are larger than males in general because maturity retards growth in males, while females continue to grow. Many Japanese are fond of eating fish eggs, thus the female fish with eggs commands a higher price than male. Although female fish are more profitable than the male, the sex of juveniles cannot be determined by external appearance and fish have been cultured in mixture of males and females.

Gynogenesis, which means development of embryos with only maternal nucleus, is an important technique for selective breeding and sex control. It will make all offsprings female in the type species with the male heterozygote (XY). Some 36 Prefectural Fisheries Experimental Stations have now studied gynogenesis using 17 fishes *(Paralichthys olivaceus, Pagrus major, Acanthopagrus schlegeli, Oncorhynchus kisutch, O. masou, O. nerka, O. rhodurus, O. mykiss, Salmo salar, Plecoglossus altivelis, Carassius buevgeri grandocutis, C. cuvieri, C. auratus, Cyprinus carpio, Gnathopogon caerulescens, Leptobotia curta,* and *Tribolodon hakonensis).*

The technique for gynogenesis involves two important steps. First is the inactivation of spermatozoa prior to insemination. Spermatozoa can be inactivated genetically by ultraviolet irradiation without damage to their mobility. Development of eggs is initiated by insemination of ultraviolet irradiated sperm. However, embryos will not survive during development because they have only half the desired number of chromosome (haploid) compared with the normal embryo (diploid). To make them survive, it is necessary to have the same number of chromosome as that of the diploid. Thus, the second important step is the inhibition of ejection of the second polar body to induce the gynogenetic diploid, which now contains 2 sets of chromosomes, from the egg nucleus and second polar body. With this method, the technique of mass production of gynogenetic diploid has been developed using 15 species of fish *(Paralichthys olivaceus, Pagrus major, Acanthopagrus schlegeli, Oncorhynchus kisutch, O. masou, O. rhodurus, O. mykiss, Plecoglossus altivelis, Carassius buevgeri grandocutis, C. auratus, Cyprinus carpio, Gnathopogon caerulescens, Leptobotia curia, Tribolodon hakonensis, and Misgurnus anguillicaudatus).*

Theoretically, chromosomes can also be diploidized by inhibition of the first cleavage. However, the survival and production rate of gynogenetic diploids through this procedure is rather low. Further improvements of this method are required.

SEX INVERSION

There is a sex inversion technique used in the mass production of all-female offsprings. Sex can be artificially reversed with sex hormones at the unstable stage of sex differentiation; thus, the female sex hormone is used for inversion to female, and the male sex hormone is used for inversion to male. When females are changed to males by sex inversion they mature like the primary male producing normal spermatozoa. In species where sex is determined by the XY system, sex in versed males will produce only X-chromosome sperms because they exhibit the XX type sex chromosomes. When they are crossed with normal females, all offspring will be of the XX type. These procedures can be used for mass production consisting of all-female seedling

In triploid male (XXY) of rainbow trout, mature triploid itself is not practical for producing sterile seedling. However, when spermatozoa of the sex-inversed male are used to induce triploidy offsprings are of all-female type and do not mature. Thus, we almost succeeded to produce all sterile seedlings (Fig. 2). This technique for producing all-female sterile fish has been developed using spermatozoa from the sex-inversed male, which is genetically female in 5 species offish *(Paralichthys olivaceus, Oncorhynchus kisutch, O. masou, O. rhodurus, and O. mykiss).*

TISSUE CULTURE

Tissue culture of laver *(Porphyra tenera* and *P. yezoensis)* has been studied in the Prefectural Fisheries Experimental Stations. Protoplasts from the leaf body of laver with excellent characteristics for seedling culture have been used.

The technique to culture protoplast has been developed to a fairly high degree but some problems persist such as the abnormal shape of the leaf body generated from the protoplast and difficulty in settling them on the laver net.

NEW TECHNOLOGY TO PRODUCE ALL-FEMALE SEEDLING OF JAPANESE FLOUNDER *(Paralichthys olivaceus)*

In 1989, production of flounder was 4,300 tons and ranked 16th among many species for aquaculture in Japan. Production has increased five times in recent years. In general, male flounder matures at 1 year of age, while it takes 2 years for the female. No difference in growth between male and female is observed up to the end of the first year, but the weight of the female is nearly twice that of the male at the end of the second year because maturation in the male retards growth. Consequently, it is more profitable to use females for commercial culture. Mass production of flounder seedling in the hatchery has been established since 1980s. However, a survey of the sex ratio of hatchery-produced flounders showed abnormally higher rate of males than in the natural population. This may be one of the reasons why many (13) Prefectural Fisheries Experimental Stations started studies on gynogenesis and triploidy in flounder to obtain all-female seedlings.

Recent studies revealed that the Japanese flounder is the male heterozygote type in genetic mechanism of sex differentiation (Tabata 1991a, b, Yamamoto et al. 1991). Consequently, all gynogenetic diploids are females with XX sex chromosome. However, most gynogenetic diploids produced by the ordinary hatchery method included many males. Sometimes over 50% of the offsprings were male, and even 100% male offsprings had been reported (Tabata 1991a). These results indicate that sex differentiation is not of the male heterogozygote type at some stage. After extensive studies, it has been shown that the mechanism of sex differentiation in the Japanese flounder may be genetically controlled by XX or XY type, and that the rearing environment may affect sex differentiation at the early unstable stage of development. Sex inversion from genotypic female to phenotypic male occurred at a high frequency in gynogenetic diploids (Tabata 1991a, b, Yamamoto et al. 1991). Accordingly, for production of all-female seedling it is necessary to do genetic as well as a physiological control to inhibit sex inversion at larval stage. A low dose of female sex hormone is needed to inhibit sex inversion from the genotypic female to phenotypic male. (Tabata 1991b, Yamamoto et al. 1991). The amount of hormone needed for inversion from the genotypic male to female is 10 or more times larger than that which inhibits inversion from female to male.

The inhibition of sex inversion from the genotypic female to male can also be done by controlling water temperatures during larval stage. Genotypic female larvae (16 millimeters in average total length) were raised for 2 months at 20°C which resulted in 93% phenotypic female. This sex ratio was similar to those treated with the female sex hormone. When the rearing temperature was increased to 25°C, the proportion of female was reduced to 66%, suggesting that water temperature may influence sex differentiation.

Production of phenotypic male which is inversed from genotypic female in gynogenetic diploids has been achieved by controlling water temperature at 25°C. Therefore, spermatozoa with only X chromosomes from these sex-inversed males can be used for all-female production. This method is simpler because it does not require any sex hormone treatment. By using the sex-inversed male, efficient mass production of all-female seedling of the flounder has been achieved.

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AQUACULTURE DEVELOPMENTS IN THE PHILIPPINES WITH EMPHASIS ON TILAPIAS AND SEAWEEDS

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ABSTRACT

Significant developments in the culture of tilapias and seaweeds in the Philippines for 1988-1991 are reviewed. The country was the top producer of the Nile tilapia *(Oreochromis niloticus)* and red seaweed, *Eucheuma* sp., in the world during the period. Intensification of cage and pond culture of tilapia in freshwater with artificial feeding was prevalent. The National Tilapia Production Program was launched in 1990 and is being implemented in 26 sites of 12 regions in the country. Culture of sex-inversed tilapias (*O. niloticus* and *O. niloticus* x *O. mossambicus* hybrids) in freshwater cages, brackishwater ponds, and sea cages was pilot-tested for the first time. For seaweeds, studies were made on the culture of other economically-important species such as *Gracilaria* sp. and *Porphyra* sp. A trial on the integrated searanching of abalones *(Haliotis* sp.) and giant clams *(Tridacna* sp.) with *Euchema* was also conducted.

INTRODUCTION

In 1990, the Philippines was the world's largest producer of Nile tilapia *(Oreochromis niloticus)* and the red seaweed, *Euchema* sp., with 78,619 tons and 291,176 tons of production. Tilapias contributed about 4% to the total fish production while dried seaweeds valued at US$49.9 million were exported for the same year. There are about 32,606 hectares of ponds, cages, and pens presently used for the culture of tilapias in addition to around 7,330 hectares of coastal waters for the farming of seaweeds in the country (BFAR 1991).

Culture of tilapia in the Philippines is mainly done in freshwater ponds and cages in lakes and reservoirs with the Nile tilapia as the major species. The Mozambique tilapia (*O. mossambicus)* is only a minor species grown in brackishwater ponds (Guerrero 1990). Two species of *Eucheuma* (*E. denticulatum* and *E. alvarezii)* are farmed in the open sea using monolines (Liana 1991).

This paper is a review of the significant developments on the culture of tilapias and seaweeds in the Philippines for the period 1988-1991.

DEVELOPMENTS IN TILAPIA CULTURE

Farming of the Nile tilapia further expanded with the intensification of pond, cage, and pen culture in freshwater. The use of artificial feeds for grow-out became prevalent. Yields of 13-20 tons per hectare in 3-4 months of rearing have been reported (Guerrero 1989, Radan 1990, Matienzo 1991). Hatchery production of sex-inversed tilapia was accelerated with the launching of the National Tilapia Production Program by the Philippine Council for Aquatic and Marine Research and Development of the Department of Science and Technology (PCAMRD-DOST).

The culture of tilapia hybrids in sea cages as an alternative livelihood for subsistence fishermen in overfished coastal waters and in "red tide"-affected areas is also being considered. In a cage culture trial conducted in northern Samar, central Philippines, the results show the feasibility of growing sex-inversed hybrids in the marine environment (Salvador, personal communication).

To produce better breeds of tilapia by selection for high growth rate, a project on the Genetic Improvement of Tilapia Species in Asia was initiated by the International Center for Living Aquatic Resources Management in 1988. A facility for the maintenance and evaluation of new African germplasm and available cultured stocks in the Philippines has been established at the National Freshwater Fisheries Training and Research Center of the Bureau of Fisheries and Aquatic Resources (BFAR) in Muñoz, Nueva Ecija Province in Luzon. Founder stocks of *O. niloticus* have been collected from Egypt, Ghana, Senegal, and Kenya (Maclean and Dizon 1989). Preliminary results show the superior growth of the Egyptian and Kenyan stocks over the Philippine stocks from Israel, Taiwan, Singapore, and Taiwan in field tests (Pullin et al. 1991). Selective breeding studies on the Nile and red tilapias are also ongoing at the Central Luzon State University's Freshwater Aquaculture Center and Aquaculture Department, Southeast Asian Fisheries Development Center (SEAFDEC/AQD) Binangonan Freshwater Substation with support from the International Development Research Centre of Canada (SEAFDEC/AQD 1991).

DEVELOPMENTS IN SEAWEED CULTURE

Studies on the culture of other economically-important species of seaweeds (other than *Euchema* sp.) such as *Gracilaria* sp. and *Porphyra* sp. were conducted by researchers of the BFAR, University of San Carlos, and SEAFDEC/AQD during the review period.

Field trials on *G. verrucosa* using natural spores and artificial substrates (adobe and hollow cement blocks) showed that production was more than double compared with that of the natural substrate (sandy-muddy bottom). Experiments on the culture of *Pophyra* sp. spores with bamboo branches as substrates were also done by the BFAR (Liana 1991).

Culture of *G. verrucosa* and *G. salicornia* in an intertidal area was tested by researchers of the University of San Carlos in 1989 (unpublished data). Their findings indicated that vegetative thalli of the two species incubated in the open area had higher growth than those of the ones incubated in the pond. Plants in the suspended or floating condition had better growth than those that were bottom-fixed.

A study on the growth of *Gracilaria* sp. sporelings and thalli in the field conducted by the SEAFDEC/ AQD show that the yield was highest in April with spacing intervals of 10 and 15 centimeters, and in February at 20 centimeters, but lowest in December at 20 centimeters. An experiment on the polyculture of *Gracilaria* sp. with sea bass *(Lates calcarifer)* in floating net cages indicates that growth rate of the seaweed decreases with increasing depth in October and November (SEAFDEC/AQD 1990). A study on the characterization of agar extracted from different species of *Gracilaria* shows that the highest agar yield and highest gel strength are obtained from *G. verrucosa* and *G. blodgettii,* respectively (SEAFDEC/AQD 1991).

An integrated searanching-seafarming trial to demonstrate the feasibility of growing *Eucheuma* sp., abalones *(Haliotis* sp.), and giant clams *(Tridacna* sp.) was conducted in a 60-square meter area in the Danajon Bank of Bohol by a private company with support from the PCAMRD-DOST in 1989. Rock mounds, each measuring one meter in diameter and spaced two meters apart, were constructed to serve as abalone shelters. Five juvenile abalones were stocked per mound. *Eucheuma* seedlings in monolines were grown in-between the rows of the abalone shelters with the giant clams. After six months, the initial results showed that the abalones doubled in size and that the seaweeds was not affected by their presence. Low survival of the giant clams in the sandy-bottom area was obtained after a strong typhoon (Ricohermoso, personal communication).

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AQUACULTURE DEVELOPMENT IN SINGAPORE

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ABSTRACT

Aquaculture production in Singapore is mainly from Seafarming and is about 2% of total fish consumed. At present, there are 79 licensed floating fish farms located in the East and West Johor Straits that culture popular species like sea bass *(Lates calcarifer)* and estuarine grouper *(Epinephelus tauvina).* Aquaculture development is geared towards the establishment of highly intensive fish farms such as land-based systems in agrotechnology parks, smaller brackishwater pond systems, and large-scale floating systems in designated sea areas. Research and development on improvement of farming techniques are on-going.

Freshwater aquaculture is focused on ornamental fish production. This is a high value trade with yearly growth of 11 % in 1986-1990. Development of intensive farming systems, improvements in water quality management, disease control, and quarantine are considered important. Research concentrates on breeding and genetics.

INTRODUCTION

Aquaculture production presently contributes about 2% of the total fresh fish supply and 14% of local fish supply. Coastal Seafarming accounted for 94.5% or 1,856 tons of Singapore's total aquaculture food fish production of 1965 tons in 1990, the rest being 48.8 tons (2.5%) of shrimp and 60 tons (3.1%) of freshwater food fish from ponds. Total value was about S$12 million. At present, there are 79 licensed floating fish farms covering 44 hectares of coastal waters of the East and West Johor Straits.

Freshwater aquaculture is mainly on production of ornamental fish. Singapore is a major global exporter of ornamental fish. Three hundred million fish, valued at S$72.6 million were exported in 1990. Singapore's exports account for about 15% of the world trade of S$500 million. The annual growth rate of Singapore's export was 11% for the period 1986-1990. To date, there are 60 licensed ornamental fish farms and 120 licensed exporters of ornamental fish.

AQUACULTURE DEVELOPMENT (INCLUDING TECHNOLOGY DEVELOPMENT) (1988-1991)

Coastal farming, which started in the late 1970s, is mainly the culture of fish in floating net cages. By 1988, there were 70 licensed floating fish farms and in 1991, there were 79 floating farms covering 44 hectares. The annual yield from coastal farming activity accounts for the bulk of aquaculture production. Floating fish farms, previously distributed in the four designated farming areas off Palau Ubin, Serangoon, and Ponggol in the East Johor Strait and Lim Chu Kang area of the West Johor Strait, are now mainly located in the Pulau Ubin and Lim Chu Kang areas because of more optimal water conditions and accessibility.

In Singapore, land-based farming is limited by availability of land. In 1987, only 3,300 hectares of land were used for farming. Only 50 hectares now remain as brackishwater shrimp ponds, about half the area previously utilized for this purpose. Less than 10 hectares are freshwater food fish ponds. Some 47 hectares of the 300 hectares aside for ornamental fish culture are now in use. In 1985, the Government introduced the concept of agrotechnology, which is the application of technology in large-scale intensive farming systems to achieve yields mat are higher than those from conventional farming systems. The Primary Production Department (PPD) promotes and initiates the development of farmlands into agrotechnology parks.

MARINE AQUACULTURE

Green mussel *(Perna viridis)* farming on ropes suspended from wooden floating rafts is concentrated in the West Johor Strait because of more suitable conditions, i.e., slower water current and the presence of plankton. Production was 1,191 tons in 1988 and 1,014 tons in 1990. Spatfall is now less frequent and abundant and growth is slower because of the decrease in the nutrient load of the waters.

Research and development on the improvement of farming methods for marine food fishes is' undertaken by the PPD's Marine Aquaculture Section (MAS). A preliminary study has been done on the use of deep net cages as a means of increasing yield within the same water surface area, and results show that sea bass *(Lates calcarifer)* yield is 4 times that which can be expected from conventional cages for the equivalent area. Trials on automatic feeding of dry formulated diet to sea bass in floating net cages gave encouraging results. With the correct adjustments in feeding frequency and feed amounts, they can be further improved. The culture of brown-marbled grouper *(Epinephelus fuscoguttatus),* a possible new species for introduction in floating net cages, has also been studied. Growth rate (from 30-600 grams in 10 months) was 70-80% slower than that of estuarine grouper (*E. tauvina)* from 30 to 600 grams in 7-8 months).

There is one sea bass hatchery in Singapore. In 1990, about 1.3 million sea bass fry and fingerlings valued at S$0.26 million were produced. Four shrimp hatcheries, mainly for the banana shrimp *(Penaeus merguiensis),* produced 141 million fry in 1990 valued at S$1.9 million. Only banana shrimp is cultured in Singapore. Most food fish fingerlings are imported. About 50,000-60,000 fry valued at about S$100,000-120,000 are imported each year. These are mainly sea bass, estuarine grouper and rabbitfish *(Siganus canaliculatus)* fry. The MAS successfully bred the brown marbled grouper in 1990 and is now looking into fry production aspects. Studies on the feasibility of using enriched diets to improve estuarine grouper broodstock performance and larval survival are also being conducted.

Trash fish is still the main feed for fish while dry formulated feeds for the tiger shrimp (P. *monodon)* which are commercially available are being used in banana shrimp culture. Five commercial companies are now producing shrimp feeds in Singapore. One company is also producing encapsulated Vitamin C and shrimp larval feed. The MAS is looking into the preparation and application of fish silage as an alternative to fresh chilled trash fish and studying the nutritional requirements and feedstuff digestibility in sea bass to develop suitable least cost formulations. The MAS also assisted two commercial companies to develop practical feed formulations for banana, tiger, and kuruma (*P. japonicus)* shrimps, and the information gained has been marketed by the commercial parties concerned.

The PPD provides fish disease and fish health management services to the industry. Common diseases and their methods of treatment have been identified and handbooks for farmers published. Farmers are also now able to recognize such diseases and apply prophylactic and therapeutic treatments with minimal supervision. A scheme for marine food fish health inspection was develop and introduced in 1990. Exporters of fish requiring health certification are subjected to a system of fish health inspection aimed at monitoring the health status of fish and management practices at export premises.

ORNAMENTAL FISH CULTURE

The aquarium fish farms have intensified production and are applying more scientific methods in fish breeding. Species that are bred and cultured locally are the live bearers, guppy *(Poecilia reticulata),* platys *(Xiphophorus maculatus, X, variatus, X, reticulata),* mollies (*P. velifera, P. sphenops, P. latipinna),* swordtail (*X. helleri),* the egg layers, angelfish *(Pterophyllym scalare),* and the tetras of the family Characidae. Farming systems used are ponds, net cages in ponds, and tanks.

Imported freshwater ornamental fish are quarantined by importers at their premises if the consignments are meant for re-export. The Freshwater Fisheries Section (FFS) of the PPD provides fish health certification services and has an accreditation scheme for exporters. This encourages them to upgrade the quality of their fish exports through management improvements. As for the marine foodfish, the PPD also provides health certification services for ornamental fish to facilitate export.

FUTURE DIRECTION

Singapore plans to increase productivity through the promotion of better management of existing farms, encouragement of large scale farming, and the application of agro technology. The private sector is given incentives to participate in the development of the aquaculture industry, such as investing in the setting up of services for the industry and in the establishment of farming systems that are demonstration models of technology application. Agrotechnology parks are being developed for this purpose. In order to operate at this level, farm units are likely to be smaller and better controlled in the future. Fish farming in floating structures are developing towards large-scale and highly intensive production systems. New species, if found to be feasible for farming and breeding, are introduced. Examples of these are gibbus snapper *(Lutjanus gibbus)* and brown-marbled grouper, blue shrimp (*P. stylirostris),* and flower or tiger shrimp (*P. semisulcatus).* Research will focus on high value productive species in the areas of breeding, farming, feed development, and disease control. Health status assessment (e.g. diagnostic kits) and the development of environmentally controlled and automated hatchery and production systems will also be addressed.

In ornamental fish culture, areas for development are in intensive farming systems that maximize production, water quality management, and automation. Other important considerations are the strict enforcement of hygiene standards and regulations, disease control, and quarantine procedures. Research will focus on the development of breeding techniques for popular species for the conservation of wild stocks and in selective breeding and genetics to improve strains such as disease resistance.

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In:F Lacanilao, RM Coloso, GF Quinitio (Eds.). Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia and Prospects for Seafarming and Searanching; 19-23 August 1991; Iloilo City, Philippines. SEAFDEC Aquaculture Department, Iloilo, Philippines. 1994. 159 p.

COASTAL AQUACULTURE IN THAILAND

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ABSTRACT

The coastal area has been explored for aquaculture and coastal aquaculture has expanded quite rapidly in Thailand. The economically important culture species are shrimp *(Penaeus monodon),* sea bass *(Lates calcarifer),* and two species of grouper *(Epinephelus malabaricus* and *£. salmoides).* The area for marine shrimp culture in 1989 was around 78,209 hectares with a production of 100,000 tons. Approximately 40% of these ponds, by area, is under intensive shrimp cultivation. The average survival rate was reported to be 40-80% with a production of 6 tons per hectare. Sea bass and grouper are mainly cultured in cages. Two cage sizes are used: 10 x 10 x 2 and 5 x 5 x 2 meters. In 1988, the production was about 1,034 and 357 tons for sea bass and grouper, respectively.

INTRODUCTION

The gulf of Thailand has a total coastline of approximately 2,800 kilometers. The coastal area has been explored for suitable aquaculture sites for a long time and this has led to rapid coastal aquaculture development in Thailand.

MARINE SHRIMP CULTURE

History

In Thailand, shrimp farming has been practiced for the last 60 years. Wild shrimp fry either enter during tidal water exchange and are trapped in the salt beds and paddy fields around estuarine areas, or are intentionally gathered from the wild and stocked directly in ponds. Production is dependent on the seasonal abundance of wild fry, which fluctuates widely from year to year.

In 1973, Thailand successfully spawned and partially reared larvae of *Penaeus* spp., such as *P. monodon* and *P. merguiensis.* The Department of Fisheries encouraged additional seedstock from hatcheries to supply traditional ponds. Supplemental feed was given in this semi-intensive shrimp farming system. A few years ago, technology for intensive farming of *P. monodon* was developed and have since been practiced in Thailand. The return on investment of intensive farming of shrimp is high, resulting in the rapid expansion of shrimp culture.

Actual and Potential Shrimp Production

At present, the culture techniques can be classified into four categories: 1) extensive (traditional), 2) semi-intensive, 3) intensive, and 4) super-intensive shrimp culture systems. These are classified in terms of pond and production per unit area per crop or per year, (kilograms per hectare per year)—from low production of less than 40 kilograms to high production in super-intensive culture systems with more than 5,000 kilograms per hectare per year.

Approximately, 40% of these ponds is under intensive and super-intensive culture system characterized by higher stocking rates, heavy feeding of quality feed, and aeration. In each crop of four months, the shrimp stock can grow to 30 pieces per kilogram when stocked at 70 individuals per square meter. Although the survival rate varied between farms, the overall average is reported to be 60-90%.

In Thailand, the tiger shrimp *Penaeus monodon* is the most common species because of rapid growth and high export value. It can be reared a length of 336 millimeters, and it is considered to have the fastest growth rate in captivity among the cultured shrimps. It usually grows to 30 grams in 4 months of culture.

There are three other closely related species: the banana shrimp *P. merguiensis,* the Indian white shrimp *P. indicus,* and *Metapenaeus ensis.* Together, they are the second most commonly cultured species in Thailand. These species do not grow big in ponds. The fry and juveniles are locally and seasonally very abundant. Some experiments on intensive banana shrimp culture have shown low survival rate and slow growth. In contrast, studies on the culture of the other two species are limited. The three species are produced in traditional and semi-intensive farms.

In 1979, over 3,300 shrimp farms with a total area of 24,675 hectares were operated. With government support, shrimp farming slowly evolved into a major agro-industry producing 100,000 tons in 1989 (Table 1). Tiger shrimp production contributed 58,000 tons in 1988 or 76%. It is projected that total shrimp production by 1995 could reach 180,000 tons.

Table 1. Coastal shrimp culture in Thailand, 1979-1989

Year	Number of form	Area (hectares)	Production (tons)
1979	3,378	24,675	7,064
1980	3,572	26,038	8,063
1981	3,657	27,449	10,728
1982	3,943	30,972	10,090
1983	4,327	35,537	11,550
1984	4,519	36,792	13,007
1985	4,939	40,769	15,841
1986	5,534	45,367	17,885
1987	7,264	52,148	25,000
1988	10,347	77,680	75,000
1989	10,347	78,209	100,000

Hatchery Techniques

Seed production techniques for *Penaeus* spp. was developed 15 years ago. The biologists were trained in Japan. There are two types of hatchery techniques. The big tank hatchery that was originally developed in Japan, and the small-tank hatchery that originated from Galveston, Texas, O.S. A. Both systems have their advantages and disadvantages, depending on environmental requirement, availability of spawners, etc. Current practice uses combined features of hatchery systems.

Hatchery Operation

Spawners are collected by fishermen from coastal waters. Spawner of tiger shrimp can be collected in the wild year-round from the east and west coast of Thailand. Eyestalk ablation and hormone injection have been successfully applied for spawner maturation in captivity.

- Some 2,000 shrimp hatcheries are operated in Thailand. These include both big hatchery and backyard hatchery (small hatchery). About 80% are backyard hatcheries. The estimated production of tiger shrimp fry in 1989 was approximately 121,000 million fry which can meet the demand of the shrimp industry in the country.

SEA BASS AND GROUPER CULTURE

History

Marine fish culture in Thailand has been practiced in ponds and cages. Sea bass can be cultured in a pond and cage while grouper is cultured only in cage because of salinity and other requirements of the species,

From the fisheries census of 1985, about 1,579 families are engaged in marine fish culture using some 600 hectares and 18,000 cages. About 87% of marine fish culture is in southern Thailand. The 1988 production of sea bass was 2,034 tons which was more than the combined production of grouper and other species (Table 2).

Table 2. Production of estuarine fish farming in Thailand 1982-1988

Year	Sea bass (tons)	Grouper (tons)
1982	145.0	-
1983	1,059.0	-
1984	473.0	176.0
1985	512.0	117.0
1986	764.0	161.0
1987	1,158.0	343.0
1988	2,034.1	357.0

Sexually mature sea bass are found in the river mouths and lagoons where the salinity and water depth range is 30-32 parts per thousand and 10-15 meters, respectively. Newly-hatched larvae (15-20 days old or 0.4-7.0 centimeters) are distributed along the coastline in estuaries while the 1-centimeter size larvae are found in freshwater bodies. Groupers cultured in Thailand are estuarine *(Epinephelus malabaricus* and *E. salmoides).* These are usually distributed in coastal and marine waters, especially along coral reefs. Grouper is a protogynous hermaphrodite; it matures as a female but transforms into a male when it grows bigger and older.

Site Selection for Cage Culture

The criteria for selecting a suitable site for cage culture of sea bass and grouper are the following:

1. Salinity range: 10-32 parts per thousand for sea bass and 20-32 parts per thousand for grouper.
2. Water depth: over 2 meters at lowest low tide. This is due to the usual size of the culture cage, which is 5 x 5 x 2 meters.

3. Current and waves: protected from strong winds, waves, and current. Ideal areas would be protected bays, sheltered coves, and similar protected waters.

4. Water quality: relatively free from domestic, industrial, and agricultural pollution.

5. Water circulation: enough water circulation to improve water quality and prevent waste materials to accumulate under the net cage.

Culture Techniques

There are two types of cages used in sea bass culture.

Floating Net Cages. The net-cages are hung on GI pipe, wooden, or bamboo frames. The cage is kept afloat by styrofoam drum, plastic carboy, or bamboo. The most convenient dimension for a cage is 5 x 5 x 2 meters. The cage unit is stabilized with concrete weights at each corner.

Stationary Net Cages. This is fastened to wooden poles at its four corners. Stationary cages are usually set in shallow bays where the tidal fluctuation is low. The size is the same as the floating net cages.

Nursery

Sea Bass. Sea bass fry and fingerlings are reared in concrete tanks up to 2.5 centimeters size. They are then transferred to nylon net cages for rearing until they reach 25 centimeters in 2-3 months.

The most convenient cage design is a rectangular cage made of synthetic netting attached to wooden, GI pipe, or bamboo frames. It is either: 1) kept afloat by styrofoam or plastic carboy or 2) stationary by fastening to wooden or bamboo poles at each corner. The size of cage Varies from 0.9 x 2 meters to 1.0 x 2.0 meters and a depth of 1.0 meter. The mesh size of the nylon net is 1.0 millimeter. After a month of nursing, fingerlings are transferred to net cages with mesh size of 0.5 centimeters.

The stocking density is about 1,000 fingerlings per cage. Grading of fingerlings is once a week during the nursery period, stocked separately for each size group. This minimizes cannibalism. Fingerlings of 2.5-5.0 centimeters are fed ground trash fish at 8-10% of body weight daily or 4-5 times a day.

The net cage is checked daily to ensure that it is not damaged by crabs or clogged with fouling organisms. It is cleaned every other day by soft brushing to maintain water circulation in the cage.

The survival rate during the nursery period is 50-80%, depending on amount and quality of feed, water conditions, and the experience of the fish farmers.

Grouper. Grouper fry are collected from the wild for culture in net cage. Grouper fry 7.5-10-centimeters long are usually collected by fish traps set in coastal waters near mangrove areas. Fry collection is done year-round but abundant from May to December.

The fish farmers collect grouper fry or buy from collectors. Before stocking, the fry are dipped in formalin solution at a concentration of 100-250 parts per million for 1 hour.

The fry are stocked in nursery cages similar to that for sea bass. Stocking is done separately for each size group since they also have cannibalistic behavior. Initially, ground trash fish is fed 3-4 times a day. Feeding is done slowly and ad libitum. The grouper fry get used to manual feeding after one week of stocking. Then, feeding is done two times a day, in the morning and afternoon. The fry are stocked in nursery cages for about 15-30 days before transferring to grow-out cages.

Grow-out

Sea Bass. Sea bass are reared from juvenile to marketable size for another 5-20 months. The marketable sizes are between 700-900 grams and 2,000-3,000 grams. The 700-900-gram fish is preferred by the local market.

Stocking density for grow-out culture varies from 13 to 300 per cubic meter depending on water conditions of the culture site. Floating cages can hold more fish than stationary cages. They are usually set in sites with better water conditions such as deeper and cleaner water, smaller salinity fluctuation, and faster circulation.

Trash fish is the main feed, and should be fresh and clean. It consists of sardines and other small marine fishes. The fish are fed slowly and feeding is stopped when the fish no longer come up to the surface.

Food conversion rates (FCR) of sea bass in Thailand range from 4.0 to 10.0:1. FCR also depends on the quality and quantity of trash fish. Normally, sea bass can grow at an average of 1 kilogram per year. Survival rates during grow-out culture are 80-95% in normal culture conditions.

The cages are checked once or twice a month to ensure they are not damaged. Nets are cleaned or changed every month. Net changes allow the farmer to check on the number and health of fish.

Cover nets are used to prevent fish from jumping out and to protect the fish from predators.

Grouper. The fish are reared in cages for 10-18 months to marketable size requirement of 700-900 grams and 1,200-1,400 grams. The fish are mostly exported live by air to Hong Kong and Taiwan. Stocking density for grow-out varies from 12 to 100 per cubic meter, depending on water conditions of the culture site.

Trash fish is also the main feed for grouper culture in Thailand. Based on experiment, grouper can be fed artificial diets easier than sea bass. Feeding and cage maintenance is the same as in sea bass culture. Food conversion rates of grouper vary with stocking density ranging from 6.0 to 7.5.

Feed is the major constraint to sea bass and grouper culture. At present, trash fish is the only food used in the first two months of culture at a feeding rate of 10% of body weight, after which feeding rate is reduced to about 5% of body weight. Since trash fish is insufficient and expensive, studies on artificial diets have been conducted, and their use for sea bass and grouper culture is still at the experimental stage.

Diseases and Prevention

Diseases may result in significant losses. Diagnosis and treatment of diseases have not been established. Common practice are preventive measures. This include provision of fresh and high-quality feed, appropriate stocking density, and suitable water quality at the culture site.

Numerous diseases of sea bass and grouper have been reported in Thailand. The causative agents of these diseases are parasitic organisms, bacteria, viruses, malnutrition, and environmental stresses.

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Prospects for Seafarming and Searanching in Southeast Asia

In:F Lacanilao, RM Coloso, GF Quinitio (Eds.). Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia and Prospects for Seafarming and Searanching; 19-23 August 1991; Iloilo City, Philippines. SEAFDEC Aquaculture Department, Iloilo, Philippines. 1994. 159 p.

OVERVIEW OF SEAFARMING AND SEARANCHING TECHNOLOGY IN JAPAN

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ABSTRACT

In 1989, artificial seed production was attained in 37 species of fishes, 16 species of Crustacea, 25 species of shellfishes, and 9 species of other fishery animals in Japan. Eighty species of fishery animal seed, including natural and artificial production, were released in natural fishery grounds during this year. The total mariculture production was 1.3 million tons. This composed of 18% fish, 35% shellfish, 46% seaweed, and 1% of other fishery animals.

In recent years, Japan achieved some success in Seafarming and searanching projects. Among these are searanching of Japanese scallop in northern Japan and acoustic habituation system of red sea bream. Searanching of striped jack using artificial seed is also explained.

FACTS ON SEAFARMING AND SEARANCHING

Artificial Seed Production

According to the Fishery Agency and Japan Sea Farming Association (Bureau of Statistics 1990), seeds of commodities that are artificially produced for stocking in Seafarming and searanching activities in Japan are given below. The changes in number of species produced and their production are shown in Fig. 1 and 2, respectively.

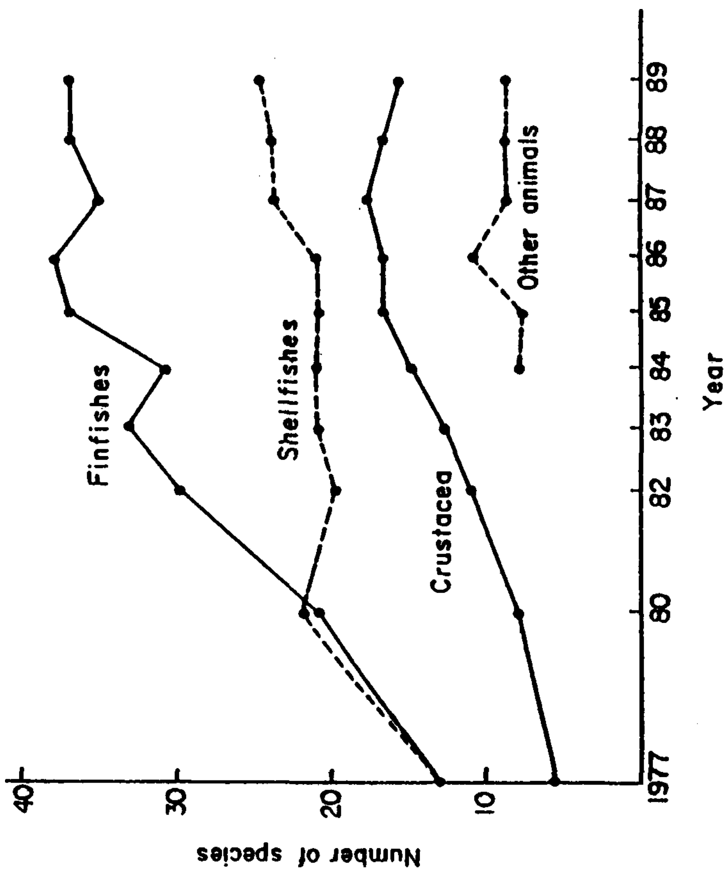


Fig. 1. Number of species per commodity for seed production from 1977 to 1989

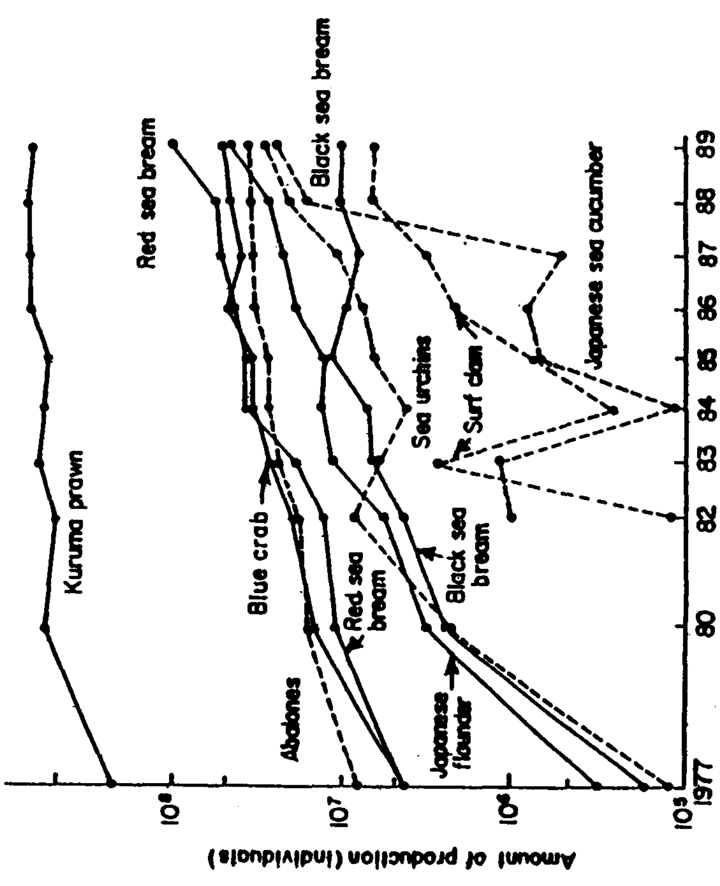


Fig. 2. Production of seeds of different species from 1977 to 1989

Fish: Thirty three species for releasing and 17 species for culture were produced in 1989. The major species of fish seed production were red sea bream (102 million individuals), Japanese flounder (46 million individuals), and flat fish (2 million individuals).

Crustacea: Sixteen species for releasing and 2 species for culture were produced in 1989. The major species of crustacean seed production were Kuruma shrimp ((723 million individuals), greasy back shrimp (41 million individuals), and blue crab (53 million individuals).

Shellfish (bivalve and snail): Twenty species for releasing and 13 species for culture were produced in 1989. The major species of shellfish seed production were Japanese black abalone (12 million individuals), yezo abalone (23 million individuals), blood ark shell (9 million individuals), and surf clam (17 million individuals).

Other fishery animals (squid, octopus, sea urchin, and sea cucumber): Nine species for releasing were produced in 1989. The major species were sea urchin (30 million individuals) and sea cucumber (27 million individuals).

Mariculture

The total amount of mariculture production in 1989 was 1.3 million tons (Bureau of Statistics 1990). This quantity of culture production was composed of 18% fishes (main species were silver salmon, yellow tail, red sea bream, and flounder), 35% shellfishes (main species were Japanese scallop and Japanese oyster), 46% seaweeds (main species were *Porphyra* and *Laminaria),* and 1% of others (Fig. 3).

Releasing

Eighty species of aquatic animal seed, including natural and artificially produced, were released in 1989 (Fishery Agency and Japan Sea Farming Assoc. 1990). The main species were red sea bream (16 million individuals), flounder (19 million individuals), Kuruma shrimp (524 million individuals), blue crab (30 million individuals), abalone (24 million individuals), Japanese scallop (3231 million individuals, almost all were natural seeds) (Fig. 4).

SOME EXAMPLES OF SEAFARMING AND SEARANCHING

Recently, restocking operations on many fishery animals were undertaken in various areas of Japan, however, except for some species, e.g. Kuruma shrimp, blue crab, Japanese scallop, and flounder, the effect of stocking was not statistically clear. Good examples of Seafarming and searanching in Japan were the introduction of Japanese scallop, red sea bream, and striped jack.

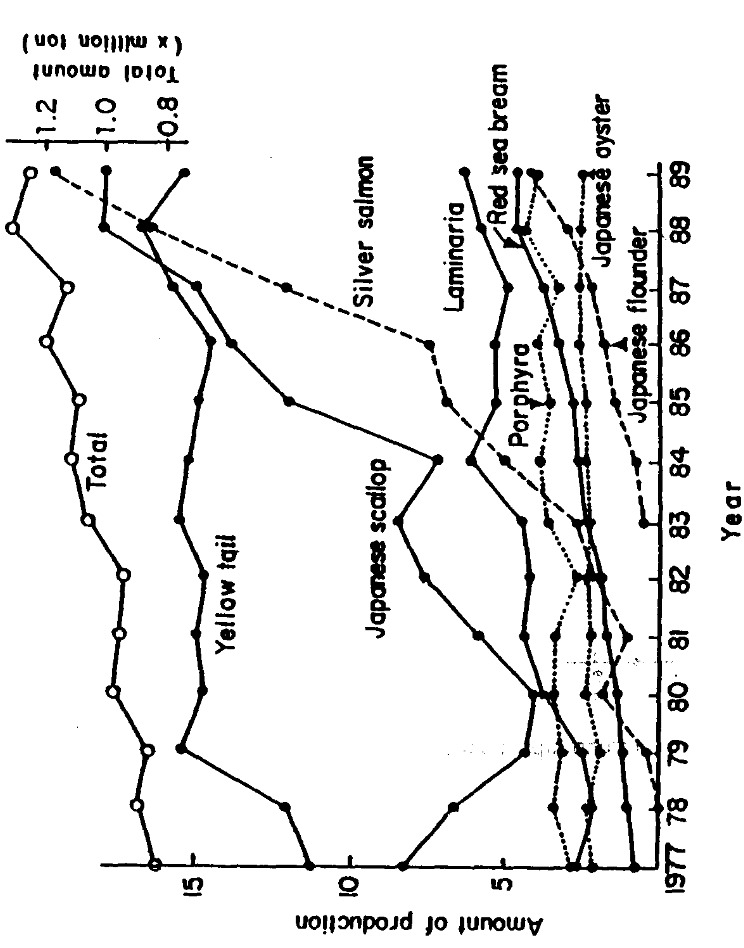


Fig. 3. Mariculture production from 1977 to 1989

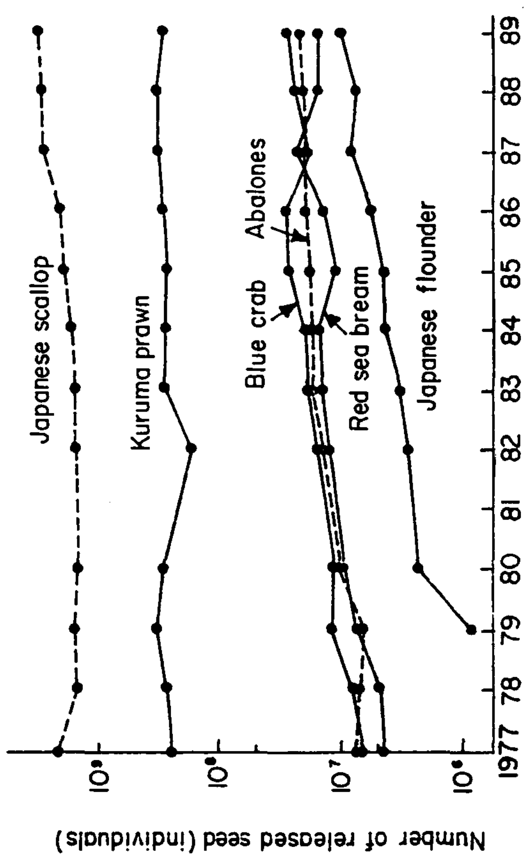


Fig. 4. Yearly change of number of released seeds, 1977-1989

Searanching of Japanese Scallop in the Northern Part of Japan

Japanese scallop is one of the most important commercial shellfishes for the northern coastal waters of Japan. In the late 1960s, the methods of natural seed collection, intermediate rearing, mariculture, and release of the Japanese scallop were established (Fig. 5). As a result of these operations, the yield of Japanese scallop increased from 20,000 tons in 1970 to 370,000 tons in 1989 (Fig. 6). This rapid production growth was due to increase in quantity of seeds collected as a result of mariculture and searanching of the Japanese scallop, which also played a role in the recruitment of stock.

Acoustic Habituation System of Red Sea Bream

Acoustic habituation system of red sea bream was tested at Kamiura-machi, Oita Prefecture, Kyushu District of Japan by Oita Prefectural Fisheries Experimental Station (Kamijo et al. 1990). Acoustic habituation system uses 300 Hz sound to condition the response of red sea bream while feeding juveniles within 2-4 weeks in a net cage. They were then released from the net cage and the sound was still used while feeding. The objective was to make the fish stay around the releasing point to observe mortality and escape from the nursery ground.

This trial was conducted from 1984 to 1987. Six groups of red sea bream that have been conditioned to acoustic habituation were released for pilot farm examination (Table 1). The result of recapture of autumn 1984 released group are shown in Fig. 7. The recapture rate after 16 months from release was 11.2% and capture points were within 2 kilometers from the release point. Total recapture rate of all groups was 11.6%. Compared with the release of red sea bream without acoustic habituation, the recapture rate with acoustic habituation was higher by 3-5%.

Table 1. Number of red sea bream conditioned to acoustic habituation and released from 1984 to 1987 (Kamijo et al. 1990)

Year	Season	Number released
1984	Autumn	66,472
1985	Autumn	66,332
1986	Spring	2,000
	Autumn	89,150
1987	Spring	3,000
	Autumn	50,000

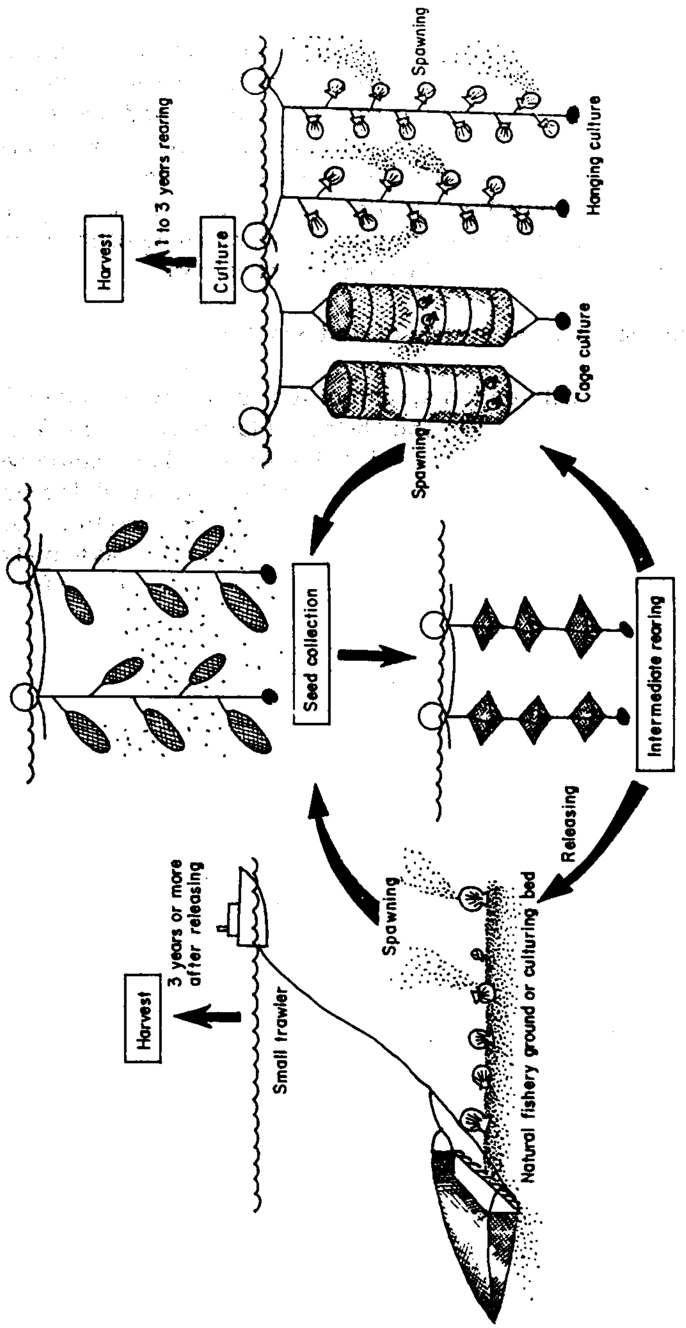


Fig. 5. Schematic diagram of mariculture and searanching of Japanese scallop

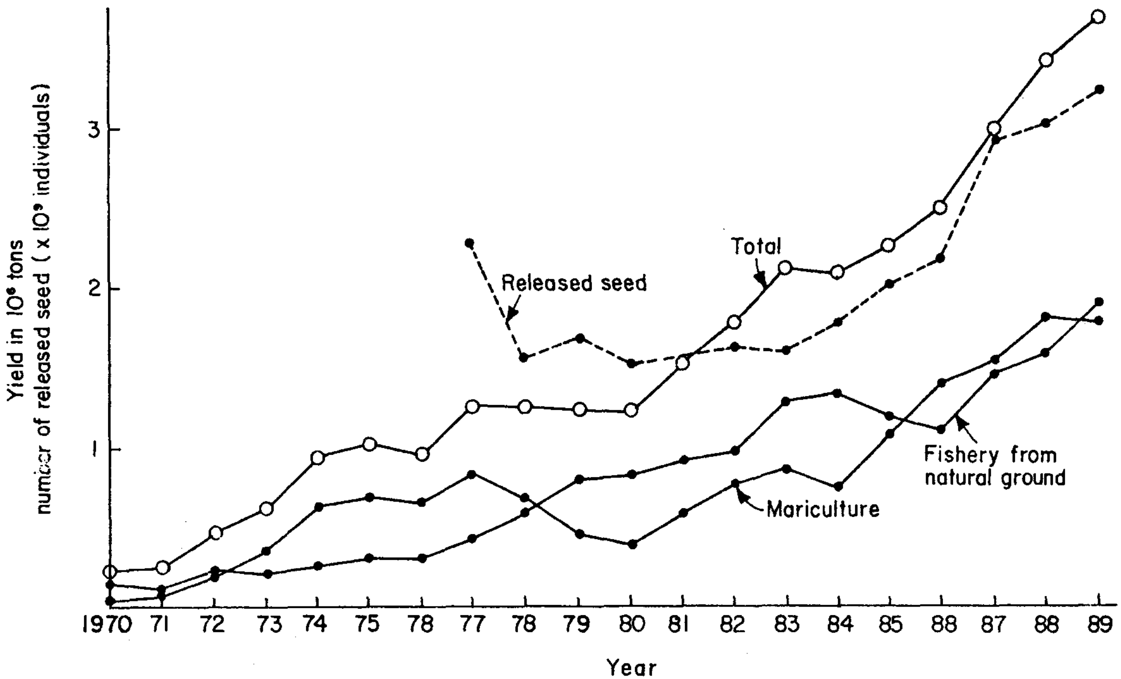


Fig. 6. Yield (mariculture, fishery from natural ground, and total) from 1970 to 1989 and number of seed released from 1977 to 1989 of Japanese scallop

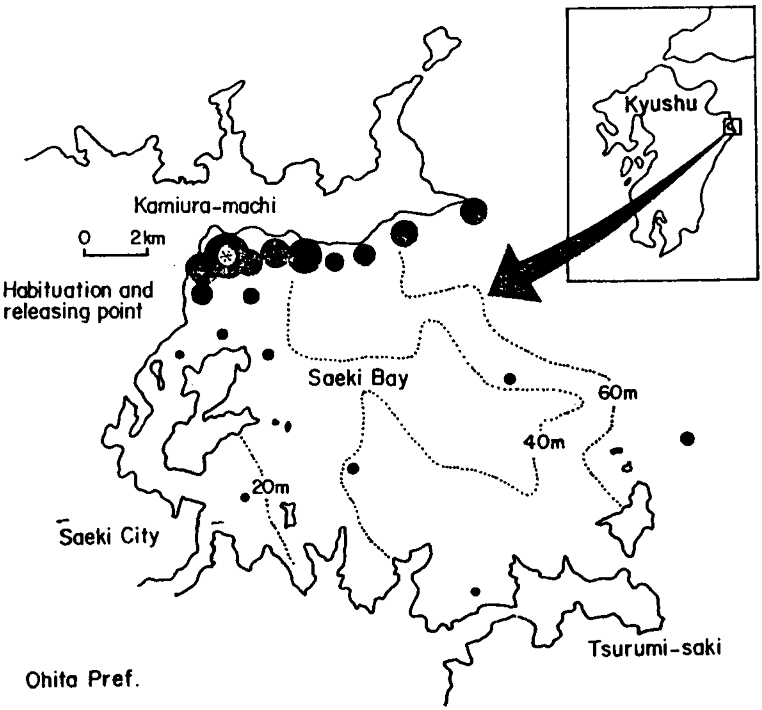
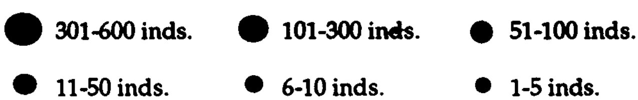


Fig. 7. Recapture area and number of red sea bream released with acoustic habituation (total number is 1,502 inds. during 16 months after release). Size of closed circles indicate the range of individuals released in an area.



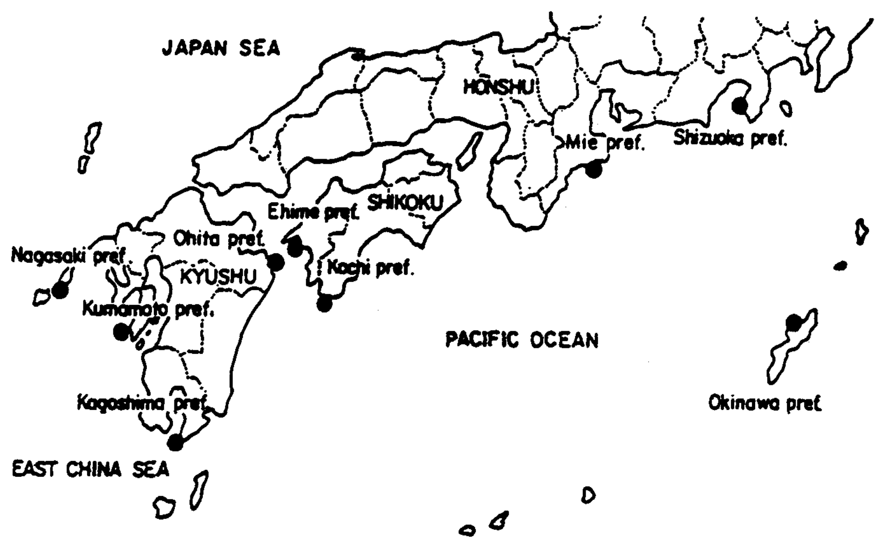


Fig. 8. Pilot farms (•) for searanching of striped jack

Searanching of Striped Jack Using Artificial Seed

Searanching of striped jack using the method of attraction to floating object and projection on the sea bottom was examined to prevent initial mortality of released fish before they grow to commercial size. Searanching of striped jack was done by setting-up into the shallow bay the culture net cage among fish artificial habitats. After release, feeding was done continuously to attract the fish to stay around and get used to the artificial habitats (Shizuoka Pref. Fish. Exp. Stn. et al. 1991).

At present, 9 prefectural fisheries experimental stations are conducting tests (Fig. 8) since 1989 with some using acoustic habituation. The studies in 1989 showed various results of inhabiting fish aggregation and recapture.

In the future, problems such as term of feeding, accretion for natural resource, and fishery management, must be addressed to implement this plan.

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SEAFARMING AND SEARANCHING DEVELOPMENT IN THE PHILIPPINES

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ABSTRACT

The paper reviews developments in Seafarming and searanching in the Philippines. Seafarming activities concentrated on seaweeds and molluscs, technology for which are already widely practiced. In Seafarming of oysters and mussels, technology is mature but only applied in traditional sites. As such, the quality of products and consumption is low due to known pollution of oyster and mussel farming areas. Seafarming of giant clams is just beginning. Hatchery techniques of producing juveniles are being refined for mass production and seeding of reef areas to enhance giant clam population. Seafarming of marine fishes is also practiced but constrained by the lack of seed stock. Sea cage fanning operators mainly depend on wild-caught fry and juveniles although the hatchery technology for sea bass has been developed. There is more research work to be done to mass-produce fry and juveniles for Seafarming of other fish species.

Seafarming and searanching appear to be the future major means of supplementing the production of animal protein by year 2000 as arable land continues to dwindle. Declining arable land area would not be sufficient to produce the food needs of the increasing population.

There is great potential for Seafarming and searanching to enhance coastal resources and produce more food. However, there is a need to provide stronger legal and institutional support for these activities to sustain development efforts.

INTRODUCTION

Searanching is a "culture-based fisheries", which is beyond the traditional practice of fish culture in an enclosed system such as fishponds. Searanching activities include increasing production in natural waters by seeding, stabilizing, and facilitating the production process for aquatic organisms of economic value.

Seafarming is a means to promote or improve growth, hence production of marine and brackishwater plants and animals for commercial use by protection and nurture on areas leased or owned (Milne 1972). Some people also consider the rearing and releasing of young fish into open bodies of water to supplement commercial fish catches as Seafarming (Iversen 1968).

Searanching and Seafarming might well be the answer to produce the animal protein requirement of the world population by year 2000. In the Philippines, arable land per capita decreased from 0.48 hectares in 1979 to 0.44 hectares in 1981 (Delmendo 1990). The industrialization process going on even use up available agricultural lands which further exacerbate reduction of agriculture production. Small land area per capita cannot produce the food needs of the population unless higher technological methods are applied.

About 70 percent of the earth is composed of marine waters. Total marine fishery production is projected to be about 150-160 million tons by year 2000, which is estimated to supply only about 30% of the projected animal protein food requirement worldwide and about 3% of the total caloric requirement. Further intensification of marine fisheries could lead to a situation in which this resource alone could supply 75% of the animal protein food requirement and about 7.5% of the caloric requirement of the world's population by year 2000 (Hanson 1974). Therefore, there is a big possibility that Seafarming and searanching will supply the greater percentage of animal protein food requirement in the near future. Technologies of Seafarming and searanching are fast developing in many parts of the globe, particularly in recent years when fish is considered a more desirable health food compared with livestock products. Seafarming zones which could be utilized for food production are illustrated in Fig. 1.

SPECIES USED FOR SEAFARMING

Molluscs, crustaceans, fishes, and seaweeds are the major organisms farmed in marine waters. Crustaceans and a few fishes are cultured in brackishwater. Molluscs are the easiest to culture as they are primary consumers. Seaweeds are also quite easy to farm but sites have to be ideal for growth. Molluscs can be moved from shallow to deeper waters without much problem.

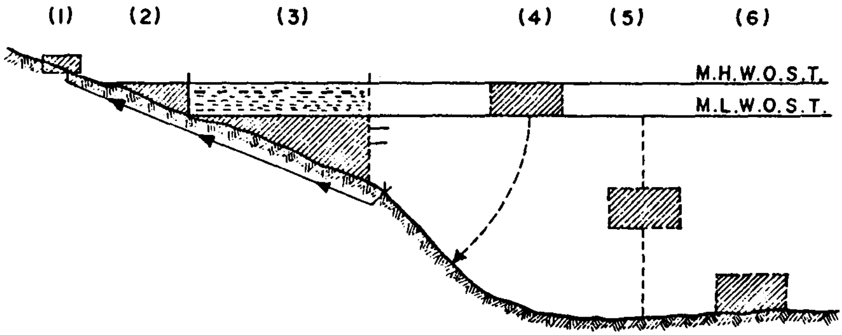

Fig. 1. The six possible zones for seafarming in coastal waters: (1) shore, (2) intertidal, (3) sublittoral, (4) surface floating, (5) mid-water, and (6) seabed. Redrawn from Milne (1972)

Oyster and Mussel

Of the molluscan species, the oysters are perhaps the earliest known marine organisms cultivated by man as early as the 4th century A.D. in Naples, Italy (Anon. 1989). This consisted of nothing but scattering broken pieces of tiles on the seabed.

Oyster farming started in 1935 in Hinigaran, Negros Occidental in central Philippines by the Bureau of Fisheries using stake method. In the same year, experimental oyster farming was expanded to Binakayan, Cavite in Luzon where different methods of farming oysters and mussels were developed. They include stake, hanging, and longline methods. The farm sites are usually shallow coastal areas on intertidal flats.

Oysters most commonly farmed in the Philippines include *Crassostrea iredalei, C. malabonensis,* and *C. cuculata.* For mussel, it is *Perna viridis.* The Philippines ranked eighth among the top 10 oyster and mussel producers worldwide (Chew 1989). In 1990, the total oyster and mussel production of the Philippines was 31,000 tons (BFAR 1990).

The methods of oyster and mussel farming are still considered traditional because farming sites used are shallow areas near coastal population centers. As such, local consumption of the product is constrained by poor water quality. Consumers are wary of eating oysters too often. Because of this, export quality standard for oysters required by importing countries cannot be met.

The Philippines can expand oyster and mussel production by shifting farming activities from shallow polluted waters to deeper, cleaner areas. The raft-type hanging and longline hanging method of oyster culture can be carried out in water depths of 5-10 meters as found in Japan and the Republic of Korea.

There are several advantages in this practice (Delmendo 1989):

1. Growth and fattening of oysters are improved.

2. Less area is needed for an equivalent production as the three dimensional use of the water is effected.

3. Culture operation can be conducted irrespective of seabed quality.
4. Available deeper areas can be used.
5. Work can be done regardless of tide condition.
6. Predator organisms are avoided.
7. Water quality is better.

In 1982, a study on the feasibility of oyster and mussel farming by municipal fishermen was conducted by the South China Sea Fisheries Development and Coordination Programme. The number of existing oyster and mussel farms were inventoried and potential areas for development were identified. There were 1,202 units of oyster farms with a total area of 429 hectares. About 9,145 hectares were available for expansion. On the other hand, there were 692 mussel farms aggregating a total area of about 300 hectares. About 4,925 hectares were potential areas available for development.

At present, neither the status of existing oyster and mussel farms nor the rate of expansion in new areas identified are known. These can be attributed to the following problems and constraints:

1. Poor monitoring and evaluation of farming operations. There is no established mechanism of monitoring and data gathering of mollusc farming operations and state of Seafarming activities of fishing households along shallow coastal areas.

2. Lack of information on larvae or spatfall density in oyster and mussel grounds. There has been no intensive survey of spatfall and distribution of oyster and mussel larvae other than empirical knowledge from oyster and mussel farmers based on their experience. They keep their oyster and mussel farming operations close to their homes. Due to lack of information on spatfall density, expansion of oyster and mussel farms could not be promoted.

3. Inadequate post-harvest processing, marketing, and distribution facilities. Some areas in the Philippines produce large quantities of mussels, but transportation and distribution network to market are not adequate. Farmers are therefore constrained to produce more due to low farm gate price.

4. Lack of demonstration of improved oyster and mussel farming management system. Oysters and mussels are sedentary animals. Therefore, their growth is dependent on the availability of food passing through. Overcrowding results in heavy competition for food. The spacing of oyster and mussel collectors should be taken into account.

5. Inadequate knowledge of growth processes of oysters and mussels. The Philippines has a year-round spawning of oysters and mussels. Some knowledge of the growth processes of oysters and mussels would be useful in the preparation of the farming schedule which synchronizes production with seed collection and growing patterns. This will stabilize the availability and price of products in the market.

Giant Clam

There has been an uncontrolled exploitation of giant clams to support the shellcraft industry because of the increasing demand for the adductor muscle of the clam. Furthermore, destruction of the coral reef habitats where these clams live account for the decline of tridacnids. *Tridacna gigas* and *T. derasa* have been seldom found in the reef areas of the Philippines, Indonesia, Papua New Guinea, Micronesia, and southern Japan (Heslinga and Fitt 1987).

Seafarming of the giant clam is needed to repopulate or replenish the wild stocks, rehabilitate the resource, and provide alternative livelihood for fishing communities. However, as an income-generating activity for small fishermen, giant clams are very slow growing; as food, not commonly consumed except in localized areas in the country.

To date, experimental work is in progress in the Philippines at the Marine Science Laboratory of the University of the Philippines-Marine Science Institute (UPMSI) in Bolinao, Pangasinan and the Silliman University (SU), Dumaguete, to mass-produce the seed to replenish the fast dwindling resources. Some results of studies conducted by these institutions have been published by the Philippine Council for Aquatic and Marine Research and Development (1988) and International Center for Living Aquatic Resources Management (ICLARM) (Munro 1993). A hatchery and culture manual on giant clam has been published by the Australian Centre for International Agricultural Research (ACIAR) in 1992 based on the collaborative research between the UPMSI, SU, the Micronesian Marine Demonstration Centre (MMDC) in Palau, and ICLARM at its Solomon Islands facility. Cultivation techniques have been developed for giant clams. However, the slow growth rate of the clam is not attractive to farmers. Government institutions may have to continue to undertake searanching of giant clam to enhance this resource. At present, exploitation of giant clam is still banned.

Better management of giant clam resources would result if shellcraft manufacturers undertake Seafarming of these clams in close cooperation with fishermen to ensure regulation of harvest.

Seaweeds

Farming of seaweeds in the Philippines has grown fast in the last decade. It was initiated in the early 1960s through the initiative of Dr. Maxwell Doty of the University of Hawaii with the collaboration of the Bureau of Fisheries. The methods of farming were demonstrated in different places in the country until extensive farming activities developed in southern Philippines, particularly, in Sitangkai, Tawi-tawi in Mindanao (Delmendo et al. 1992).

The major species cultivated are the red seaweeds, *Eucheuma cottonii, E. spinosum,* and *E. alvarezii.* The method used is the monoline technique described in the Manual of Seaweed Farming: 1. *Eucheuma* spp. (Godardo 1988). There are about 3,000 hectares of seaweed farms in Mindanao and central Visayas (Smith 1987). The extent of *Eucheuma* seaweed farming fluctuates depending on the local buying price and demand for the raw material. This particular industry is characterized by output price fluctuations and cost shocks due to the oligopsonistic structure of the industry. *Eucheuma* farming is an industry that is composed of closely related groups of buyers and sellers organized to perform the economic activity of seaweed marketing in a particular manner (Hollenbeck III 1983).

Dried seaweed is one of the major export products of the Philippines. In 1990, a total of 35,346 tons of dried seaweeds were exported with a total amount of Pl,192,331 (US$49,883) Freight on Board. This excludes the seaweed extracts, the carrageenan, processed by seaweed processors based in the country (BFAR 1990). The Philippines is the major source of *Eucheuma,* which is the raw material for carrageenan extracts.

Caulerpa sp. is a seaweed species farmed in brackishwater ponds. It is mainly used for domestic consumption. However, recent developments on post harvest handling of the seaweed promoted its export. *Gracilaria* sp. is another species which used to be grown in fishponds. Seedstock used to be obtained from Manila Bay and planted in ponds to serve as food for milkfish, but this is no longer practiced. Wild stocks have decreased due to reclamation of Manila Bay and pollution. Small scale farming of *Gracilaria* is practiced in western Visayas using ponds and drainage canals (Hurtado-Ponce et al. 1992). Production was found higher in canals than in ponds. *Gracilaria* is now being farmed in other parts of the Philippines such as eastern Sorsogon mostly in open coastal waters. A manual on *Gracilaria* farming has been published by the FAO/UNDP project, Seaweed Production Development (Taw 1993). Farming trials are being conducted at various sites to demonstrate techniques of production and determine environmental factors affecting gel quality of agar extracts from *Gracilaria.*

Marine Fishes

Fishes commonly farmed include the sea bass, *Lates calcarifer,* and the grouper, *Epinephelus* spp. These are usually cultured in protected coastal areas or in ponds.

Seeds are obtained by spawning and collection of juveniles from the wild. Spawning the sea bass has been quite developed and hatchery technology for this species had been handed down to farmer level in Thailand, Singapore, and Indonesia. In the Philippines, collection of juveniles from the wild is found to be more practical and economical particularly for grouper. The farming of these species has not expanded as fast as the farming of shrimp because of the lack of feeds and seed stock.

The technology of marine fish cage culture using sea bass and groupers is already a packaged technology which farmers have adopted. The major constraint which needs to be solved is the supply of fish seeds and feeds for grow-out purposes. Much work has been done on hatchery production of sea bass and groupers. However, mass production of seeds of these species has not come about to encourage fish farmers to go into marine fish culture. To ensure a high rate of survival from hatching to juvenile stage, further research work is necessary to mass-produce the seeds for Seafarming purposes. In addition, the search for alternative feed for use in cage culture operations other than trash fish should be developed.

Shrimps

Shrimp farming activities (largely *Penaeus monodon)* take place in brackishwater ponds. There are about 220,000 hectares of brackishwater ponds in the country, which are primarily used for the culture of milkfish *(Chanos chanos).* With the technological advances attained in hatchery production of shrimp juveniles and the high demand for shrimp in the world market, some of the milkfish farms were converted into shrimp farms using the improved farming techniques practiced in Taiwan. A recent survey of brackishwater ponds in specific regions in the country shows the area now used for shrimp farming is about 23,446 hectares (Table 1).

Table 1. Estimated production and area used for shrimp farming in different regions of the Philippines (Anon. 1989)

	Farming System and Area (hectares)				
Region	Extensive	Semi-intensive	Intensive	Total	Estimated Production (tons)
01	86.1	110.4	199.3	395.7	1,886.2
02	52.2	2.0	-	54.2	48.6
03	7,281.6	106.5	12.7	7,400.8	5,511.9
04	171.3	449.9	5.0	621.2	1,492.1
05	666.8	72.0	4.0	742.8	1,838.9
06	3,773.0	3,719.5	430.7	7,923.2	17,029.9
07	1,288.0	625.5	384.8	2,298.3	5,664.1
08	333.8	-	-	333.8	233.7
09	549.3	10.0	-	559.3	414.5
10	825.5	437.0	38.9	1,301.4	2,180.7
11	86.9	37.4	35.0	159.3	435.5
12	1,352.7	270.8	32.5	1,656.0	2,002.8
Total	16,467.2	5,836.0	1,142.9	23,446.0	36,654.5

The aspect of shrimp farming that is closely related to Seafarming is the hatchery production of juveniles. Shrimps spawn in coastal areas. Shrimp hatcheries are often located close to the sea for convenience of seawater supply. Broodstocks collected from the wild are kept in broodstock ponds for maturation and spawning. The technique of spawning by eyestalk ablation has been an established practice.

Spawners collected from the wild are still preferred for spawning purposes. Experience of hatchery operators indicated that it is more economical to use wild-caught spawners than to raise breeders in captivity. Furthermore, it was found that ablated shrimps were not good due to low survival of spawn. Shrimp fry produced from pond-grown ablated broodstocks were not as hardy as those obtained from the wild. Thus, it is important that mature shrimp population in nature should be adequate to provide spawners for the hatchery. Furthermore, there would be better chance of reproduction, thus increase the shrimp resource productivity.

The problem of lack of broodstock can be solved by searanching, restocking of coastal lagoons with shrimp juveniles to supply spawners for hatchery use.

SEARANCHING

In the Philippines, searanching has not been attempted because government efforts for resource enhancement has not been given appropriate support and attention. Seeding of lakes and reservoirs is a practice continued by the government but releasing of juvenile fish or shrimps into coastal waters has not been attempted. This is due to the vast expanse of the sea compared to inland waters such as lakes and reservoirs. Besides, the mass-production of seeds of marine species has not been attained. Although much work have been carried out in spawning the milkfish, sea bass, and groupers, large quantities of seeds to satisfy the needs of searanching has yet to be attained.

Searanching, to be of significant impact, should be undertaken by the users of coastal fisheries resources. Under the present open access and common property nature prevailing in marine fisheries, searanching would be difficult to launch unless the government is prepared to subsidize the mass-production of seeds. The fishermen themselves, with technical guidance of government, should be able to produce the seeds they need to release within their communal fishing areas. Furthermore, a system of coastal resource use and allocation should be established as a matter of policy of government.

In the case of shrimps, the excess juveniles, produced from existing hatcheries could be released in selected coastal areas particularly when there is an oversupply from the hatcheries. This is one way of stabilizing the price of shrimp fry when production exceeds demand. Searanching of shrimp could be taken up by the shrimp hatchery operators as they would directly benefit from the increase of the broodstock population in the wild.

Experience in Japan showed that shrimp searanching increased production of shrimps in the Hamanako lagoon 2-4 times greater than natural catches in open waters. The advantages of shrimp ranching are: 1) increased supply of shrimp breeders and increased production, 2) stabilized production through adjustment of the time in releasing the postlarvae, and 3) additional recruitment to the natural production of shrimps not caught for breeding purposes (Uno 1985).

Searanching of marine fishes

Searanching of marine fish species, such as milkfish, mullet, snappers, groupers, siganids, spadefish, etc. could be made possible by mass-production of their seedstocks which could be released in coastal waters. Research work must be intensified to develop the technology of cheap mass-production of seedstocks of these species. Otherwise, searanching and even Seafarming would not fully develop in the same magnitude as the brackishwater fish farm industry.

Searanching is a means of resource enhancement and part of this program is the production of seedstocks in hatchery and nursery facilities. Broodstock rearing and maintenance for hatchery use is an aquaculture operation, both in land- or marine-based facility. Once the seeds are already produced and released, these become part of the natural fishery in the coastal waters which are available to the fishermen for harvest.

For searanching to become a universal practice, fishermen and seafarmers must be given appropriate incentive by the government in terms of legal and institutional support.

FUTURE OF SEAFARMING AND SEARANCHING

There is great potential for development and expansion of Seafarming and searanching. However, there is yet a need to mass-produce a large number of marine fish seeds in hatcheries to supplement wild caught species by fishermen. A low-cost mass rearing technique of marine fishes of high economic value has not yet been fully developed. Unless there are inexpensive hatchery rearing techniques to produce large numbers of juvenile fishes, it may not be economical to enhance coastal fishery production through Seafarming or searanching operations. Furthermore, the common property nature of marine waters and open access policy do not promote searanching. There is no ownership of fish seedstocks once released in open waters. Searanching would require collective effort of those who are engaged in fishing activities. On the other hand, seafarmers could claim ownership of seedstock in enclosed facilities such as cages and pens installed in certain water areas for which a lease or permit for their use has been obtained.

The communal nature of coastal waters is subject to dispute by several users. Unless this is specified by law, some legal problems in the occupancy and development of Seafarming sites could arise. The necessary legal and institutional support for Seafarming and searanching as part of coastal fisheries management and development should be established, backed by a strong policy decision and political will of the government.

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SEAFARMING AND SEARANCHING IN SINGAPORE

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ABSTRACT

Seafarming in Singapore is described in detail, covering farm design and structure, site selection criteria, current farm practices, farm operation and maintenance, species for culture, and diseases and their control.

Searanching has not been done in Singapore. Results of related work on fish stocking is briefly reported.

SEAFARMING: SPECIES CULTURED AND PRODUCTION STATISTICS (1988-1990)

Farming in floating net cages accounts for the bulk of food fish produced in Singapore. In 1988, 1,972 tons from Seafarming were produced. Fishes (471 tons, 23.9%) were mainly the sea bass (235 tons, 11.9%), groupers *(Epinephelus tauvina, Plectropomus maculatus, Cromileptis altivelis)* (141 tons, 7.1%), golden snapper *(Lutjanus johni,* 49 tons, 2.5%), and others like the yellowfin jack *(Caranx ignobilis),* golden trevally *(Gnathodon speciosus),* bream (*Acanthopagrus* sp), and rabbitfishes *(Siganus canaliculatus* and *S. guttatus)* (46 tons, 2.3%). Shellfishes (1,501 tons, 76.1%) were mainly the green mussel *(Perna viridis,* 1,191 tons, 60.4%), mangrove crab *(Scylla serrata,* 256 tons, 13%), banana shrimp *(Penaeus merguiensis,* 30 tons, 1.5%), and spiny lobster *(Panulirus polyphagia,* 24 tons 1.2%).

In 1990, the 1,856 tons production from Seafarming was fish (614 tons, 33.1%), mainly the sea bass (304 tons, 16.4%), groupers (186 tons, 10%), golden snapper (49 tons, 2.6%), yellowfin jack, golden trevally, and bream remained as minor species (59 tons, 3.2%). New fish species that have become popular are the humpheaded wrasse (*Cheilinus undulatus,* 4 tons, 0.2%) and gibbus snapper (*L. gibbus,* 11 tons, 0.6%), and shellfish (1,242 tons, 66.9%) are mainly the green mussel (1,014 tons, 54.6%), mangrove crab (151.5 tons, 8.2%), banana shrimp (39 tons, 2%), and spiny lobster (37.5 tons, 2%).

Over the period 1988-1990, fish production increased by 34.3% (143 tons). This was due to increases in production of popular species like the sea bass and groupers (especially the red grouper) and the demand by the Hong Kong market for high priced, new species like the humpheaded wrasse and gibbus snapper, which are imported for culture. Shellfish species like the spiny lobster have increased in popularity both locally and overseas. Production increased from 24 tons in 1988 to 37.5 tons in 1990. Green mussel and mangrove crab production decreased. Mangrove crab imports from Indonesia and Sri Lanka are more frequent, but more consignments are now being directly channelled to retail outlets because of high local demand. The Primary Production Department (PPD) established a Marine Fish Farming Scheme and enacted the Fish Culture (Control and Licensing) Rules in 1981. Floating fish farms are licensed at S$500 annually for an area of 0.5 hectares. Fourteen fish farms are associated with palisade fish traps. This is about half of the palisade traps still existing, and demonstrates that fish farming is a more lucrative activity.

CULTURE SYSTEM IN SEAFARMING

The floating cage system is presently the only one used for the culture of fishes and crustaceans. The design of the farm structure has generally remained unchanged and is basically a wooden pontoon (32-55 wood pieces, depending on size) of joined wooden frames (mostly 3x3 meters) provided with a work house. The structure is floated by plastic or molded drums, usually of 200-250-liter capacity. The actual farming structure is about 1,500 square meters and is anchored within the licensed space of 5,000 square meters. Polyethylene net cages, in which fish or crustaceans (like shrimp and lobster) are cultured, are suspended from the frames. Cage design and materials vary according to the type of animal being cultured, namely fish, shrimp, lobster, or crab.

Green mussels are farmed on ropes suspended on floating rafts. The design of the floating raft for mussel farming is also a wooden pontoon floated by plastic drums. The pontoon has cross beams for suspending culture ropes. Each pontoon may be 5x5 meters, 15x5meters, or 15x10 meters, and is located in sheltered coastal waters of 8-10 meters depth at low tide, with the long axis parallel to the tidal current. Spats are collected on 2 meters of nylon ropes. Mussels are grown out on 2-4 meters of polyethylene ropes tied at intervals to pieces of old netting material and immersed at four ropes to one square meter.

The systems that are described are based on prototypes developed by the PPD in the early 1980s. Information is available in handbooks published by the PPD. The Marine Aquaculture Section (MAS) provides field and other services as and when required. Commercial farm structures are made by the fanners themselves or the work is contracted out to carpenters and experienced palisade trap operators. Cages are constructed by the farmers or contracted out to fishermen. Net cage designs are also provided by the PPD.

FARM SITE SELECTION FOR SEAFARMING

Site selection criteria, as laid down by the PPD, are based on factors like the availability of sheltered water area such as the Johor Straits where all Seafarming activities are presently found and the physical, chemical, and biological characteristics of the water. Water depth is at least 5 meters for standard net cages of 3 meters deep. This gives the net cage bottom a clearance of 2 meters at lowest water. Maximum depth of the selected site is less than 20 meters to facilitate anchoring of the farm structure, otherwise this becomes difficult and more costly. Other physical criteria are wave height (less than 2 meters), tidal current characteristics such as current velocity (less than 50 centimeters/second), water turbidity (less than 10 milligrams/liter), and water temperature (27-31°C).

Chemical criteria such as salinity, dissolved oxygen, pH, organic nutrient, and heavy metal loads are also taken into consideration in site selection. Salinity is in the range of 26-31 parts per thousand; dissolved oxygen, greater than 5 parts per million; pH, 7.8 - 8.3; organic load as Chemical Oxygen Demand, less than 3 parts per million; nutrient load as ammonia-nitrogen, less than 0.5 parts per million, and heavy metal loads of less than 0.0004 parts per million for mercury, less than 0.01 parts per million for copper, less than 0.03 parts per million for cadmium, less than 0.1 parts per million for lead, nickel, zinc, and antimony, and less than 1 part per million for manganese, iron, chromium, and tin.

Biological criteria are the intensity of fouling by organisms such as the brown mussel (*Modiolus* sp.), green mussel, marine worms, tunicates, bryozoans, and algae; and frequency and occurrence of phytoplankton and dinoflagellate blooms. Deterioration and sudden changes in the environment, such as the non-toxic dinoflagellate blooms of *Cochlodinium* sp., result in fish mortalities or disease outbreak because of stress to the fish. Mortality is further aggravated by the crowded conditions in intensive culture, off-feeding and restlessness. Economic losses can be significant as mortalities can range from 10-100%. Fortunately, this problem is infrequent and more oxygen can be made available to the fish through aeration and agitation of the water.

Oil spills also affect the availability of dissolved oxygen. Strict enforcement of sea traffic regulations, high standards in water pollution control, and the excellent flushing effect of tidal currents minimize oil pollution and mitigate its effect. Fish farming activity is also kept away from the major navigational channels as a precautionary measure. With early warning of an oil spill, net cages can be protected by a canvas shield around the farm structure since the oil usually occupies the top 0.5 meters of the water. Fish are not fed during an oil spill since this causes unnecessary disturbance of the water and also increases oxygen demand.

SEAFARMING METHODOLOGY

The PPD has laid down guidelines for husbandry and farm management. Farmers have also learned from experience, and made their own improvements and innovations.

SPECIES SELECTION

Potential aquaculture species fulfill the criteria of high market demand, seed availability, and intensive stocking. Other than the species commonly cultured, potential species for Seafarming are the threadfin (*Polynemus sexfasciatus*), gibbus snapper, and brown-marbled grouper. Shrimp species with potential are more suited for land-based farming systems.

STOCKING, HARVESTING, AND TRANSPORTATION

The PPD has published guidelines for stocking of fingerlings and grow-out sizes. After 6-8 months, the fish are about 35 centimeters (700 grams) and 1.5-2.0 tons or more are harvested per 5X5X3 meters net cage with 90% survival.

In practice, most fish for culture are purchased as small fingerlings of 3.0-7.5 centimeters (2-6 grams) because they are cheaper and easier to transport. Some of the consignments are sanitized on-farm to get rid of ciliate parasites. The farmer frequently culls and transfers the largest and smallest individuals to other net cages. In about 1-2 months, most of the stock are ready for grow-out.

Harvested fish are transported in aerated fiberglass tanks on small boats to landing points where they are transferred into aerated large fiberglass tanks on lorries which bring them to restaurants and other destinations.

FEEDS AND FEEDING

Trash fish is still used as feed in Seafarming. Supplementary supply comes from the waste catch of palisade traps.

Fingerlings are fed minced or finely chopped trash fish, while grow-out fish are fed trash fish chopped to various sizes. Feeding is done twice daily, usually in the morning and towards evening, and at slack tide when the tidal current is weakest. This minimizes losses from feed swept away by the tidal current. Trash fish is fed to the cultured animals in small quantities at a time to cut down on wastage. Fingerlings are given trash fish up to 10% of their weight daily, while fish in their early grow-out stage are fed up to 8%. Late grow-out fish are fed 3-5% until they attain 600-800 grams. Food conversion ratio (FCR) is about 5-6:1.

The MAS conducts studies to evaluate nutritional requirements of the sea bass and digestibility of feed materials with the aim of formulating low cost diets, which give optimal performance. Other studies have included the use of deep net cages for fish culture and using dry pelleted feed dispensed by automatic feeders.

DISEASE AND CONTROL

Diseases do not reach epizootic proportions, and serious mortalities are usually confined to the farm, affecting fish in net cages within close proximity-Diagnostic services are available to fish farmers who consult MAS. Farmers are also taught to recognize early signs like off-feeding and abnormal swimming behavior and to detect and treat common diseases. They can consult the PPD's Fisheries Handbook on Common Diseases of Marine Foodfish.

Common diseases are bacterial infections caused by *Vibrio parahaemolyticus* and *V. algynoliticus,* which are present in coastal waters and are opportunistic, causing secondary infections in cultured fish under stress. Ectoparasite infestations are caused by ciliates, *Cryptocaryon irritans, Trichodina sp., Brooklynella* sp., and the digenean trematode *Diplectanum* sp. The presence of a picorna-like virus in the brain of imported young sea bass fry and fingerlings may explain high mortalities encountered by farmers, besides those caused by transportation stress. The extent and value of fish losses have not been estimated, but stress and disease can account for 20-80% loss in the first few weeks after stocking.

Control of disease by preventive measures and the practice of good farm management is by far the most effective. Deterioration and sudden changes in the environment have been linked to mortalities or outbreaks of diseases in cultured marine fishes, disease and mortality being often the result of stress. Plankton blooms are usually due to diatoms or dinoflagellates and last for about 5 days. So far, these blooms have not been toxic, However, annual fish losses due to non-toxic plankton blooms are second in importance only to mortalities caused by transport stress. Neap tides concentrate blooms over fish farming areas. Immediate fish kills are apparently caused by asphyxiation. A week or two later, deaths from secondary bacterial infections reach their peak.

The protection of farmed fish lies in minimizing contact between fish and plankton blooms. This is done by (1) using deep cages in areas where conditions are favorable, thus allowing fish stocks to stay below, (2) wrapping the entire farm's perimeter with a 2 meters deep canvas shield to prevent entry of the bloom into the cages, (3) pumping air at high pressure and volume on to net cage bottoms, and (4) drawing up bottom water and spraying on to net cages, or (5) towing the farm sections to safer areas.

FARM OPERATION AND MAINTENANCE

Farm operation involves mainly net cage changing and cleaning, and the husbandry practices described. The net cage is cleaned monthly. Fouling is removed by high pressure water jet. Net cages are dried and checked for damage.

The raft structure is repaired every 1-2 years and metal parts replaced every 1-3 years. Fouling on drum floats that are usually plastic drums is removed every 2-3 months by scraping and repainting with antifouling paint. Farms that are floating with dangerously low freeboard are contacted by the PPD for rectification to be made.

SEARANCHING

Searanching is not done in Singapore, although a preliminary study on the rehabilitation of a part of Singapore River was made in July 1986-December 1990, including artificial seagrass implantation. Results showed that sea bass, stocked at Boat Quay made-their niche in the vicinity, and that artificial seagrass provides a good hiding place for sea bass and indigenous fauna. However, heavy siltation caused the strands to collapse and to reduce the availability of hiding space after about 2 weeks.

An effective searanching program for Singapore would require the necessary expertise, staff and facilities, identification of suitable locations, establishment of a fish stocking program assessment of appropriate methodology, and making improvements in fish stocking methods including studies on artificial habitats and audio recall.

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SEAFARMING AND SEARANCHING IN THAILAND

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ABSTRACT

Seafarming is undertaken in the coastal sublittoral zone. Different marine organisms such as molluscs, estuarine fishes, shrimps (pen culture), and seaweeds are cultured along the coast of Thailand. Seafarming, especially for mollusc, is the main activity in Thailand. The important species are blood cockle, oyster, green mussel, and pearl oyster. In 1988, production was approximately 51,000 metric tons in a culture area of 2,252 hectares.

Artificial reefs have been constructed in Thailand since 1987 to enhance coastal habitats. Larvae of marine organisms have also been restocked in the artificial reef area.

INTRODUCTION

The total coastline along the Gulf of Thailand and Andaman sea is approximately 2,600 kilometers. A relatively long period has been spent in surveying coastal area for suitable aquaculture and this resulted in the rapid expansion of coastal aquaculture in Thailand.

Different marine organisms such as molluscs, estuarine fish, and seaweeds are cultured along the coast of Thailand.

MOLLUSC FARMING

Mollusc culture has been practiced in Thailand for more than 100 years. In the early days, fishermen cultured molluscs by collecting spats from natural grounds. At that time, culture practices were traditional, developed by people living along coastal areas suitable for mollusc farming. Mussel and oyster culture originated from gathering of spats from abandoned stakes of fixed fish traps, and subsequently grown on bamboo poles and palm trunks. Bottom culture of cockles and, to some extent, mussel culture was also practiced. Rock culture of oysters, using cement blocks and natural rocks, is now common. Numerous improvements have since been introduced to increase production.

Species which are collected from natural grounds and cultured are the following:

	Species	English Name
1.	*Anadara granosa*	blood cockle, ark shell
2.	*Anadara nodifera*	blood cockle, ark shell
3.	*Perna viridis*	green mussel
4.	*Modiolus senharrsenri*	horse mussel
5.	*Saccostrea commercialis*	oyster
6.	*Crassostrea lugubris*	oyster
7.	*Crassostrea belheri*	oyster
8.	*Pinctada maxima*	gold lipped pearl oyster
9.	*Pinctada margarifera*	black lipped pearl oyster

Only the first seven in the list are described in this paper. The pearl oysters are mostly used for the pearl business rather than for human consumption, and their culture methods are kept secret.

In 1988, mollusc culture area covered a total of 2,252 hectares. These are divided into green mussel (351 hectares), horse mussel (86 hectares), blood cockle (1,198 hectares), and oyster (617 hectares). Estimated production of cultured mollusc and those collected from natural grounds is about 44,236 tons green mussel, 1,858 tons oyster, 4,652 tons cockle, and 652 tons horse mussel (Table 1).

Blood Cockle

The blood cockles farmed in Thailand and Malaysia belong to the *genus Anadara,* family *Arcidae,* and generally inhabit fine muddy bottom near the shoreline.

Suitable sites for cockle culture are estuarine areas and along the coastline with muddy bottom and with seawater salinity of above 13 parts per thousand. They are usually in wind-sheltered bays with a river or canal to bring in food supply. A suitable area should have a bottom slope below 15 degrees to prevent

Table 1. Mollusc culture in Thailand showing total culture area production and value during 1984-1988

Species	1984			1985			1986			1987			1988		
	Area (ha)	Prod'n (tons)	Value	Area (ha)	Prod'n (tons)	Value	Area (ha)	Prod'n (tons)	Value	Area (ha)	Prod'n (tons)	Value (xUS$1,000)	Area (ha)	Prod'n (tons)	Value (xUS$1,000)
Blood Cockle	1,473	12,512	-	1,911	12,375	-	1,589	6,928	-	1,665	9,609	1,770	2,041	4,652	1,265
Green Mussel	365	26,217	-	420	25,906	-	498	11,905	-	491	23,949	1,756	583	44,236	3,740
Oyster	988	4,851	-	969	3,516	-	995	580	-	1,028	1,483	699	1,049	1,258	1,017
Horse Mussel	46	1,608	-	90	361	-	87	272	-	87	818	1,022	87	652	77
Pearl Oyster	53	1,608	-	43	-	-	43	-	-	43	-	-	63	-	-

cockles from being moved by wave action. Water depth should preferably be between 0.5 and 1.0 meter and the exposure period should not exceed 2-3 hours a day. In addition, the culture area should have low population of predators.

Oyster

There are four species of oysters widely distributed along the coast of Thailand. Three, *Saccostrea commercialis, Crassostrea lugubris,* and *Crassostrea belcheri,* are commercially cultured.

Oysters require a hard substratum for attachment and can thrive on wood, stone, or rock substrate. Three principal methods of oyster culture are used: the stake, stone or concrete block, and the hanging (raft and longline) methods. *Saccostrea commercialis* are cultured by the sowing method on hard, sandy, and rocky bottoms. Most suitable areas for oyster culture are located near river mouths which are protected by natural or artificial barriers against strong wind and wave action.

The salinity level should not drop below 9.5 parts per thousand for long periods and the water should contain enough nutrients for plankton production. Water depth can be 1.0-2.0 meters (below mean sea level), and the exposure period should not be more than 2-3 hours a day during spring tides.

Green Mussel

The cultivation of green mussels in Thailand follows the traditional system of collecting on stationary fishing gear, or on bamboo poles. There are three basic methods for green mussel culture which are similar to the method practiced in oyster farming.

Green mussels are distributed along the entire coastline of Thailand and are particularly abundant near river mouths. Suitable areas for green mussel culture should have a salinity of 15-32 parts per thousand. Water depth should be 1-4 meters below mean sea level. Phytoplankton productivity should be optimum with regard to species composition and abundance to sustain high productivity.

Horse Mussel

Horse mussel is another bivalve species widely distributed along the coastline of Thailand. It requires hard bottom with a good mixture of silt, sand, and mud in order to thrive. They inhabit shallow waters with depths usually less than 2 meters and may be exposed for short period (less than 1 hour a day) during low tides.

This mussel requires a different habitat from that of the green mussel and, like cockles, usually grows on the bottom of intertidal zones.

At present, horse mussel is cultured only in Chanburri province (inner Gulf of Thailand) in an area of 240 hectares. No specific survey has been done on horse mussel culture. However, it is assumed that this species requires an aquatic environment similar to cockles, except for the texture of the bottom substrata.

SHRIMP PEN CULTURE

Pen culture of the tiger shrimp *(Penaeus monodon)* has been practiced in Thailand since 1987. Postlarvae (50 days old) are stocked at a rate of 100-200 per square meter nylon pen of 36 square meters. Suitable sites for pen construction are found along the river mouths with water salinity of 10-31 parts per thousand and depth of 2-5 meters. Artificial feed and trash fish are given 3-4 times a day. Harvesting is usually done on the fourth month when the shrimps have reached a size of 28 grams. Production is about 100 kilograms per pen (Table 2).

SEAWEEDS

Thailand does not use large quantities of seaweeds, hence these are only harvested from natural beds. The Department of Fisheries is conducting research on the feasibility of mass propagation, particularly of some species of *Gracilaria* and *Polycavernosa.* These are widely found in Trat, Chanthaburi, Songkhla, and Pattani provinces. Local fishermen collect and dry the seaweeds, which are sold to middlemen and mostly exported. Price is about US$1.20 per kilogram.

ARTIFICIAL REEFS

Due to decline in coastal fisheries catch in Thailand, the government realized the urgent need for coastal resource enhancement. A program to construct artificial reefs was first developed in Rayong in 1987 to enhance fish stocks.

Materials such as used tires and concrete blocks have been used for artificial reef construction. Several shapes and appropriate models have been developed in many coastal areas of the country.

The young marine organisms, such as fish fingerlings, shrimp fry, mollusc larvae, have been restocked in the artificial reef area. Post-deployment studies were carried out. They include: 1) materials, shapes, and depths at Rayong, 2) models, fishing records, and subsidence rates at Songkhla, 3) models for deterring the operation of trawlers and purse seine at Nakhorn Srithammarat, Songkhla, and Pattani, and 4) fishing record, species composition, and siltation places adjacent to and away from estuarine areas at Satun.

The Department of Fisheries cooperated with Southeast Asian Fisheries Development Center to conduct studies on oceanography (physical and chemical), biology, and socioeconomics at Rayong and Petchburi.

Table 2. Pen culture of tiger shrimp in Thailand showing total culture area, production and value during 1987-1990

Province	1987			1988			1989			1990		
	Area (sq m)	Prod'n (kg)	Value (xUS$1,000)	Area (sq m)	Prod'n (kg)	Value (xUS$1,000)	Area (sq m)	Prod'n (kg)	Value (xUS$1,000)	Area (sq m)	Prod'n (kg)	Value (xUS$1,000)
Bangpakong	1,980	3,575	21	10,080	18,200	109	14,400	26,000	156	15,012	15,012	163
Songkhla				11,850	14,163	113	97,000	11,155	89	64,000	32,000	256

The following are considerations before artificial reefs are deployed:

1. Fishing gears prevailing in the locality. For example, artificial reefs should be deployed deeper than 15 meters if hook and line prevails in the area.

2. The models of artificial reef in relation to fish habitat.

3. Water depth should be deeper than 7 meters.

4. Current, wave, and wind.

5. Artificial reefs could accelerate coral reef formation. Buoys are placed as markers for fisherfolk in those areas.

6. Cost should not exceed US$30 cubic meter or US$15 per square meter and should last longer than 7 years.

According to the Sixth National Social Economic Development Plan, artificial reef deployment is targeted to cover at least 100 square kilometers for conservation purposes.

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PROSPECTS OF SEAFARMING THROUGH THE FISHERIES SECTOR PROGRAM (PHILIPPINES)

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ABSTRACT

The status and problems confronting the fisheries sector are discussed. An exploratory discussion of the five-year Fisheries Sector Program addressed on aquatic resources regeneration, conservation, and sustained management of coastal fisheries, production intensification in aquaculture within limits of ecological balance, and commercial fishing away from over-fished areas into the deeper water is made. Seafarming as one of the alternative livelihood for a large number of coastal subsistence fishermen is emphasized particularly in the 12 priority bays under the program to uplift their economic condition. Rapid resources assessment in the 3 priority bays during the first year of the program implementation pinpointed existing aquaculture practices, potential sites for Seafarming and recommended species for culture. The credit, extension services, and training components of the program are envisioned to enhance Seafarming development in the country.

INTRODUCTION

Fisheries as an economic sector accounted for 3.8% of the Gross National Product in 1990 (BFAR 1990). It made a significant contribution to the national economy in terms of income, employment, and export earnings. Fish production during the year was about 2.5 million tons, of which 73% came from capture

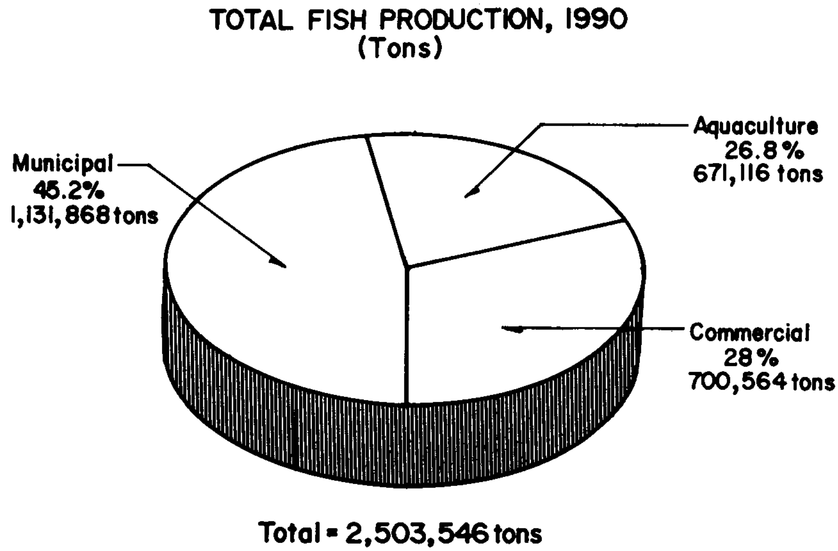

Fig. 1. Total fish production by sector, 1990

fisheries and 27% from aquaculture (Fig. 1). The fisheries industries also gave employment to about one million fisherfolks, 750,000 were fishermen and 250,000 were in aquaculture operations. Total export earnings in 1990 was US$474 million.

Over the years, the sea has provided its natural bounty to many fishermen and their families making the Philippines the 11th largest fish producer in the world (FAO 1988). Aquatic resources were gathered indiscriminately in large quantities annually. Continuous fishing took place without consideration to conservation, regeneration, management, and limitation of the fishery resources, until it was realized that the coastal waters which used to be the most biologically productive area of the sea is over-exploited. The coastal waters is now beset with the problems of over-exploitation caused by illegal fishing, habitat destruction, intense competition between fishing groups, and other pressures. Fish production records from traditional fishing areas by the Bureau of Fisheries and Aquatic Resources (BFAR) showed a down trend since 1975 (BFAR 1987), affecting the socioeconomic conditions of sustenance fishermen.

With the deteriorating state of capture fisheries, focus was directed to aquaculture. It is recognized that this area is the most stable and profitable in terms of production, efficient use of resources, and employment (Bardach et al. 1972).

Aquaculture in the Philippines is practiced in three types of environment: freshwater (fishponds, fish pens, and cages in lakes and reservoirs), brackish water (milkfish and shrimp ponds), and marine (Seafarming or mariculture). The latter which is the managed cultivation of fishery resources from the shoreline to the sublittoral zone of marine waters (Hansen et al. 1981, Palma et al. 1989), is the least practiced in the country, although it has the most potential. The archipelagic nature of the Philippines, consisting of about 7,100 islands, offers a vast coastal area where mariculture activities can well be undertaken. These are the coves, bays, inlets, estuaries, reef flats, and lagoons. Seafarming offers an alternative livelihood to sustenance fishermen while waiting for the fishery resources to regenerate.

STATUS OF SEAFARMING IN THE PHILIPPINES

Seafarming or mariculture in the country involves three major commodities: seaweeds, shellfishes, and fishes. Each commodity contributes a significant percentage in the overall production in aquaculture during the past four years (Table 1). The status of the Seafarming industry as of December 1990 is discussed below:

Seaweeds Culture

Seaweeds are the most important product of Seafarming in terms of export. Since 1985, it has ranked third among the fishery export of the country (BFAR 1988,1990). Records of BFAR showed that from a production of 85,824 tons in 1978, it rose to 291,176 tons in 1990 (BFAR 1990). This consisted mainly of *Eucheuma* spp. cultured in an estimated area of 5,700 hectares in western Mindanao and central Visayas, with a small percentage gathered from the wild. Other species cultured in ponds, to a limited extent, are *Gracilaria* and *Caulerpa.* Another seaweed of commercial value that is gathered from the wild is the *Sargassum.*

The culture of seaweeds in the country was enhanced by the private sector because of its commercial value. In foreign markets, the Philippines has established its identity as the fourth among the world producers of seaweeds

Table 1. Comparative production in different sectors of aquaculture from 1987 - 1990

Sector	Production (tons)			
	1987	1988	1989	1990
1. Brackishwater fishpond	267,814	240,206	253,580	265,814
2. Freshwater fishpond	30,105	32,922	34,238	35,816
Fish pens	35,588	23,814	24,102	24,379
Fish cages	17,789	18,263	19,502	20,931
3. Seafarming				
Oyster	10,361	12,445	12,819	13,485
Mussel	11,644	15,502	16,403	17,515
Seaweeds	220,839	256,405	268,701	291,176
Total	594,140	599,557	629,345	671,116

supplying 70% of the demand for carageenan (Rabanal 1986). Exported carageenan is usually in semi-refined or refined form as there are now existing processing plants in the country.

The local seaweed industry is beset with problems that hinder its expansion (Rabanal 1986). Among these are: inferior quality products caused by poor postharvest handling, weak marketing system causing unstable price of the product which discourages farmers to produce more, disease called "ice-ice", lack of quality seedlings which are resistant to diseases, and natural calamities. Few studies have been conducted to solve the problems.

Shellfish Culture

The coastal waters abound with marine shellfish but only oyster *(Crassostrea* sp.) and green mussel *(Perna viridis)* have been farmed since the 1940s. Farming sites are in open waters, limited to areas with natural spatfalls. Although transplantation to other areas has been successful (Aypa 1979), the process has not been widely adopted.

Culture methods used are still traditional with minor innovations. The hanging method using rafts for suspension and the longlines for mussel culture in deeper waters were successfully tried but not adopted (Rabanal 1985). The rope webb proved to be effective in producing mussels in commercial scale but is capital intensive and causes siltation when installed in shallow waters.

Although the shallow water culture is being- practiced, production of shellfish can be comparable to that of other countries in terms of quantity. Delmendo (1989) reported that the Philippines ranked 8th among the oyster and mussel producing countries in the world.

The potential for expansion of the industry is great (Glude et al. 1982), particularly with over 10,000 hectares identified as suitable area for shellfish farming (Figs. 2-3) (Rabanal 1982, Delmendo 1989).

Other shellfish with culture potentials and awaiting development are abalone *(Haliotis* sp.), cockle *(Anadara),* scallop *(Amusium* sp.), windowpane oyster *(Placuna placenta),* and angel wing shell *(Pholas orientalis).*

Fish Culture

Seafarming of fish is still young in the country. It was started on a limited scale about three years ago. The commercial demand for grouper, sea bass, siganid, and snapper stirred the interest of some fish growers. To date, fish cage projects in central Luzon, western Mindanao, and other regions have been reported (Basa 1988). The greatest bottleneck of the industry, however, is the insufficient supply of fingerlings. Except for sea bass, which can be successfully produced in the hatchery, grouper fingerlings come from the wild which is seasonal and uncertain. The smuggling of grouper fingerlings to other Asian countries aggravates the problem. Foreign buyers offer higher prices for fingerlings resulting in the prohibitive cost locally which is disadvantageous to local fish culturists.

1. Buguey, Cagayan (NG, FA)
2. Ilocos Norte (NG, FA)
3. Ilocos Sur (NG, FA)
4. Aringay and Sto. Tomas, La Union (NG, FA)
5. Lingayen Gulf and Tambac Bay, Pangasinan (NG, FA)
6. Agno River, Manat, Binmaley, Pangasinan and Davel, Dagupan City (NG, FA)
7. Binuangan and Malolos, Bulacan (NG, FA)
8. Abucay and Mariveles, Bataan (FA, NG, PS)
9. Bacoor and Ternate Bays, Cavite (NG, FA)
10. Balayan Bay, Batangas (NG, FA)
11. Batangas Bay (NG, FA)
12. Tayabas Bay (PS)
13. Makato, Aklan (PS)
14. Sapi-an Bay, Capiz (NG, FA)
15. Banate Bay, Iloilo (NG, FA)
16. Bacolod (Port of Banago) (NG, FA)
17. Binalbagan and Hinigaran, Negros Occidental (NG, FA)
18. Himamaylan, Negros Occidental (PS)
19. Panguil Bay, Misamis Occidental
20. Luuk, Bongao Cave, Sacol Island, Zamboanga del Sur (PS)
21. Atoll Lagoon, Sta. Cruz Zamboanga del Norte (PS)
22. Malalag Bay, Davao City (NG, FA)
23. Del Carmen Dapa, Surigao del Norte (PS)
24. Calape, Bohol (NG, FA)
25. Cebu (NG, FA, PS)
26. Leyte (PS)
27. Maqueda Bay and Jiabong Samar (PS, NG)
28. Catbalogan, Samar (PS)
29. Sorsogon (NG, FA)
30. Calauag Bay, Quezon (PS)
31. Alabat Island, Quezon (PS)
32. Polillio Island, Quezon (PS)

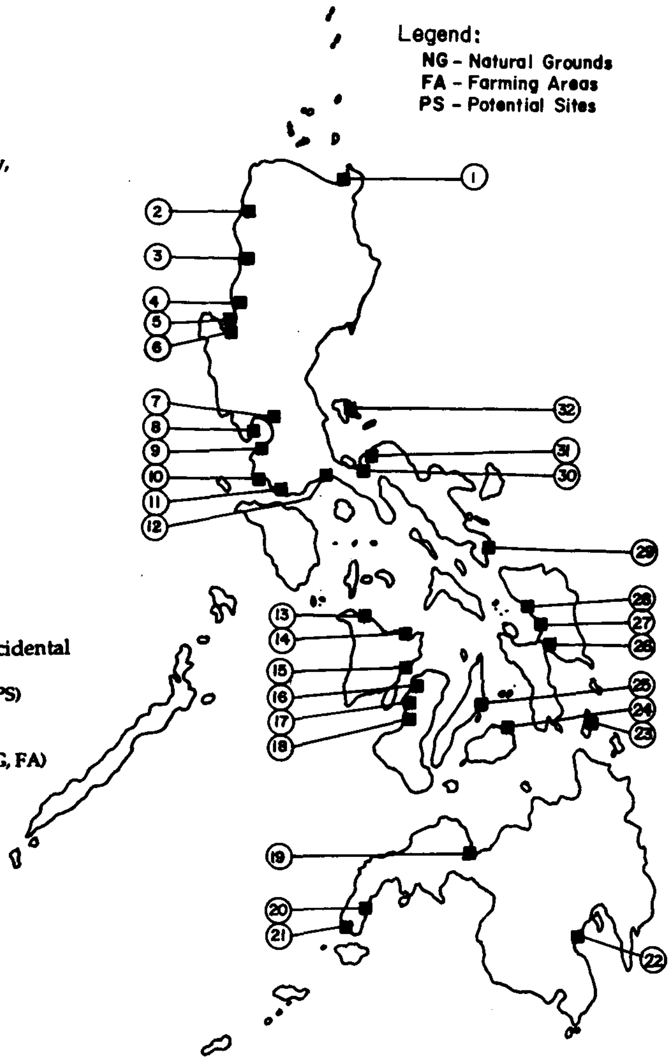

Fig. 2. National oyster grounds, forming areas, and potential farming sites in the Philippines. (Source: SCS/82/WP/103.)

1. **Masinloc, Zambales (NG, FA)**
2. **Binuangan, Obando, Bulacan (NG, FA)**
3. **Bacoor and Binakayan, Cavite (NG, FA)**
4. **Tayabas Bay, Quezon (FA, PS)**
5. **Aklan (PS)**
6. **Sapian Bay, Capiz**
7. **Banate Bay, Iloilo (NG, FA)**
8. **Bacolod City (NG, FA)**
9. **Binalbagan and Hinigaran, Negros Occidental (NG, FA)**
10. **Himamaylan, Negros Occidental (NG, FA)**
11. **Bohol (PS)**
12. **Babatngon, Leyte (PS)**
13. **Maqueda Bay, Samar (NG, FA, PS)**
14. **Catbalogan, Samar (FA)**
15. **Sorsogon Bay, Sorsogon (PS)**

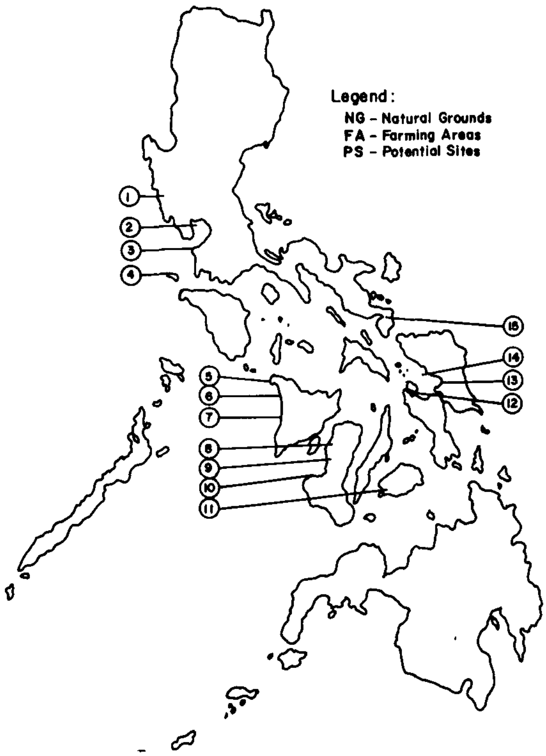

Fig. 3. National green mussel grounds, farming areas, and potential farming sites in the Philippines (Source: SCS/82/WP103)

Another problem affecting the industry is the lack of trash fish to feed carnivorous species. Unless formulated feeds for these species are made available using local and inexpensive ingredients the development of the industry will be slow. Other species which feed at a lower trophic level should be tried.

Financing is another constraint to the industry. Fish cage culture is capital intensive and sustenance fishermen are not able to engage in it unless a low-interest financing scheme is made available to them.

THE FISHERIES SECTOR PROGRAM

The Fisheries Sector Program (FSP) is the first coordinated effort between the Philippine Government, the non-government organization (NGOs), and the fishing communities to rehabilitate the degraded coastal waters and enhance productivity and alleviate the extensive poverty of the sector. It is a five-year program that recognized that fisheries management and regeneration could be effected through concerted action of the government and the fisherfolks to sustain future economic growth (FSP 1990). This is being implemented by the Department of Agriculture through the Bureau of Fisheries and Aquatic Resources (BFAR)

The primary objectives of the Program are:

1. Regeneration and conservation of aquatic resources with emphasis on balancing fishing effort to maximum sustainable yield;
2. Rehabilitation and protection of the coastal zone environment;
3. Alleviation of poverty among municipal fishermen particularly through diversification of their sources of livelihood;
4. Improvement of aquaculture production but within limits to maintain ecological balance; and
5. Inducement of commercial fishing away from overfished nearshore waters and into the 200-mile exclusive economic zone.

The program has six components, namely: fishery resources and ecological assessments, coastal zone management, research and extension, law enforcement, credit, and infrastructure.

For the coastal zone management component, the coverage would be the 12 priority bays (Fig. 4) which are traditional fishing grounds selected according to the immediate needs of resource regeneration, environmental degradation, poverty level of fisherfolks, and initiative in self-regulation. These bays are:

1.	Manila Bay	Metro Manila, Cavite, Pampanga, Bulacan, and Bataan
2.	Calauag Bay	Quezon
3.	San Miguel Bay	Camarines Sur and Camarines Norte
4.	Tayabas Bay	Quezon Province
5.	Ragay Gulf	Quezon Province and Camarines Sur

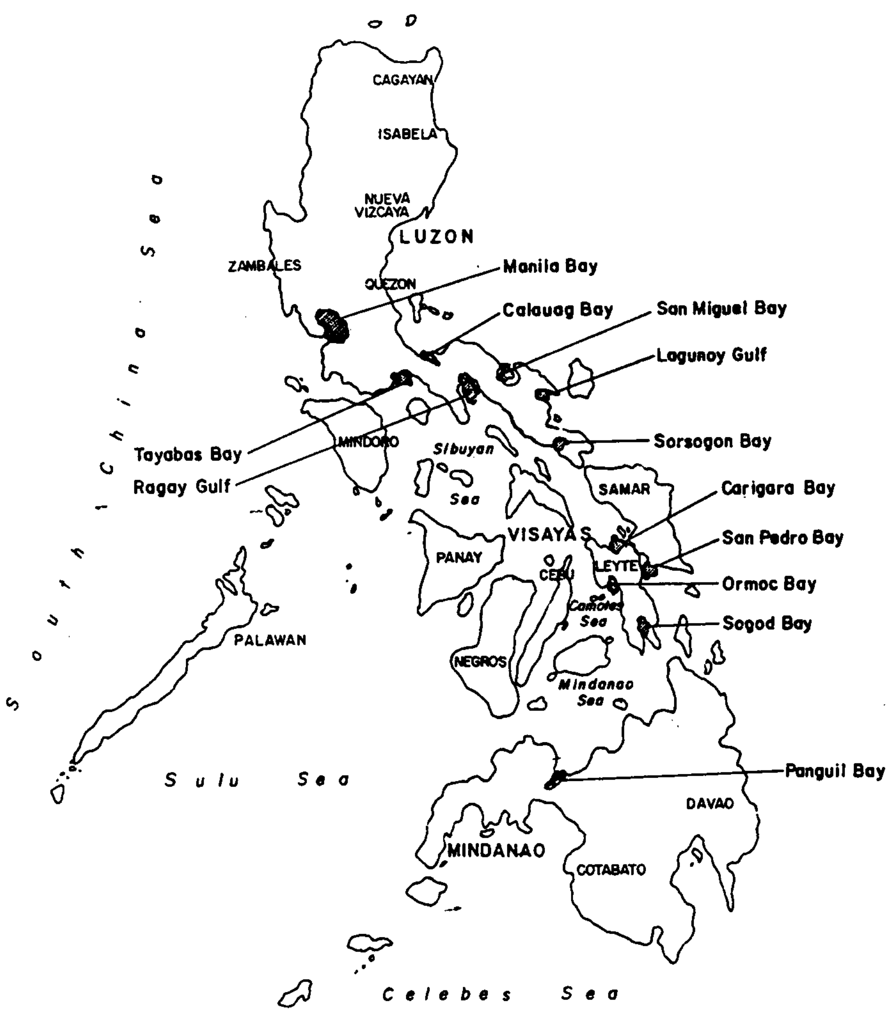

Fig. 4. The twelve priority bays under the Fisheries Sector Program

6.	Lagonoy Gulf	Camarines Sur, Albay, and Catanduanes
7.	Sorsogon Bay	Sorsogon
8.	Carigara Bay	Leyte
9.	San Pedro Bay	Western Samar, Leyte
10.	OrmocBay	Leyte
11.	Sogod Bay	Southern Leyte
12.	Panguil Bay	Misamis Occidental, Lanao del Norte, and Zamboanga del Sur

Initially, only three bays are covered during the first year (1990) of the Program implementation namely: Calauag, Carigara, and Panguil Bays. But within five years, all the bays would have been assessed of its resources, and rehabilitation and management measures instituted.

For aquaculture, assessment of fishponds particularly those under the Fishpond Lease Agreement would be done in the following Regions:

1.	Region I	Ilocos
2.	Region III	Central Luzon
3.	Region IV	Southern Tagalog
4.	Region V	Bicol
5.	Region VI	Western Visayas
6.	Region IX	Western Mindanao

Criteria for selecting the above regions was the extensive acreage of existing fishponds.

Potential of Seafarming under the Program

Under the different components of the program, Seafarming would be directly or indirectly benefited. The following discussion relates each component to Seafarming.

Fishery Resource and Ecological Assessment

To provide a scientific foundation for rational management, studies and monitoring of the fishery resources, habitats, ecological parameters, and socio-economic indicators will be undertaken in the offshore, nearshore, and inland areas of the bays. Data collected would be analyzed and stored in a National Fishery Information System Office, to be established within the Department of Agriculture.

With data available on the fishery resources and environmental conditions existing in each, seafarmers or sustenance fishermen would be guided in selecting the most appropriate aquaculture activities to engage in as well as the commodity to be cultured and placement of the project. Information on suitable sites for mariculture would also be made available (FSP 1991). An example is in Calauag Bay, Quezon. Before the rapid resource assessment study, little was known about its resource and the nature of the habitat. After the survey, it was found that potential areas for mariculture existed. These are the sites along Apud Bay and Lopez Bay, within the vicinity of Niogan Island (Fig. 5). Extensive growth of seagrasses in the locality enhance the abundance of fry/ fingerlings of siganids and groupers collected in February to April thus revealing a new fry ground for these commercially important fishes. Giant clams (*Tridacna* sp.) were also found thriving in the reef portions of the bay.

Rapid Resource Assessment study conducted in Panguil Bay showed that an extensive mariculture industry like seaweed culture, crab fattening, cage culture of grouper, milkfish, and squid are now existing in the bay which have never been reported. More areas for development of mariculture industry were also identified.

Coastal Resource Management

This component is the core of the resource and environmental rehabilitation thrust of FSP. The significant decline in the fishery harvest from the once rich coastal resources of the country reflects a lack of effective resource management brought about by overcrowding, overfishing, illegal fishing, habitat degradation, and competition among user groups of the resources.

As a basic strategy, community based initiatives in resource management will be encouraged. The government, in cooperation with NGOs will organize and train fishermen to undertake resource enhancement measures like establishment of fish sanctuaries and marine reserves, construction of artificial reefs, transplantation of corals, and reforestation of mangrove areas. Viable alternative projects will be developed and piloted to draw the attention of fishermen into other economic activities to relieve pressure on already overfished coastal waters. Seafarming would be the appropriate alternative livelihood for these fishermen.

Research and Extension

The component thrust of the program is the preparation of a Comprehensive National Fisheries Research Program, networking and upgrading of existing research facilities, manpower development through provision of scholarships and trainings, expansion of extension services, conduct of priority studies on searanching and fish farming, impact evaluation of artificial reefs, and red tide monitoring.

Seafarming, which is faced with many problems, would greatly benefit from this program. Some of these problems are highly technical in nature, requiring research and development which entails high cost, that only the government and research institutions can support. Among the research areas are: refinement of existing technologies, verification of existing technologies not adopted but with prospects of adoption to increase production, and technol-

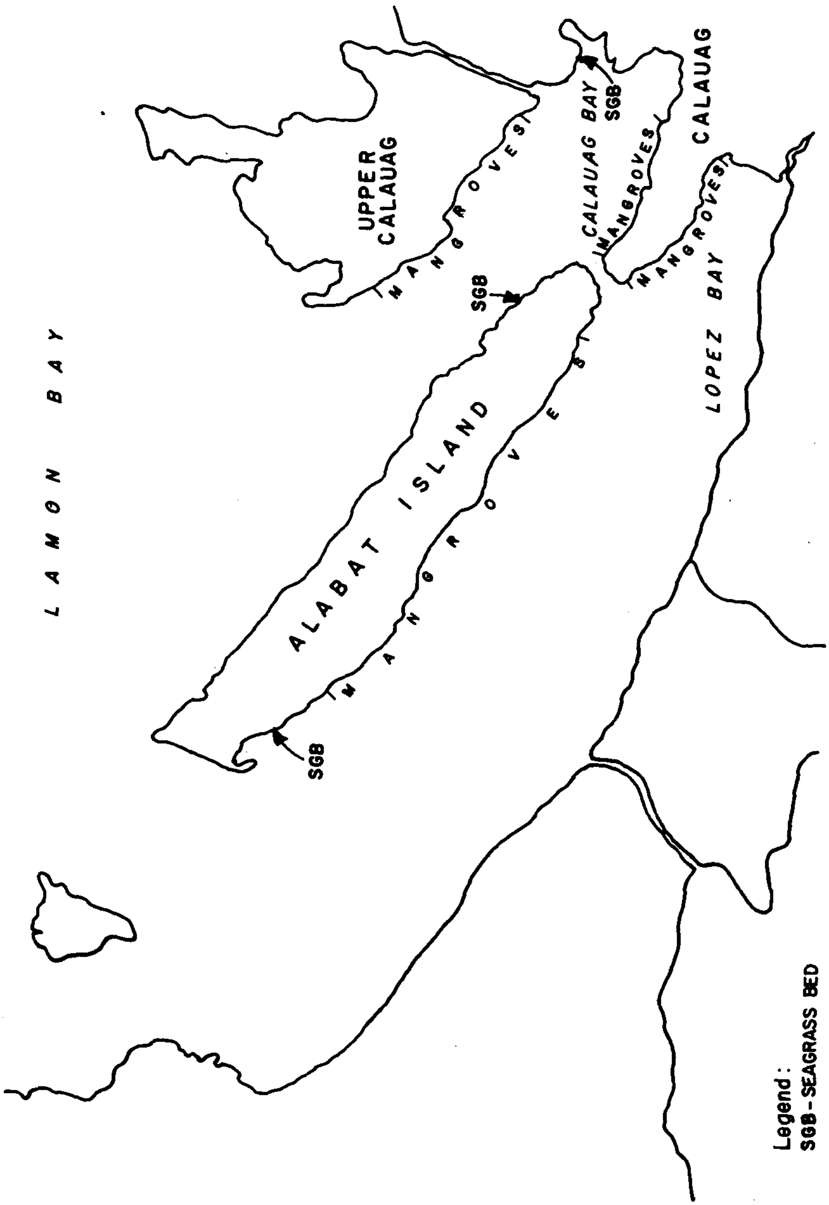

Fig. 5. Mangroves and seagrass beds of Calauag Bay

ogy generation on the culture of some fishery resources with aquaculture potential, especially for species which are already over-exploited (Rabanal 1985, 1986).

An example is the present interest on grouper culture. The source of seedlings for groupers, sea bass, siganid, and snapper is the wild. The seasonal abundance and occurrence in different parts of the country of these highly economical and important species should be studied to support the growing industry, while the hatchery techniques for the mass production of seedlings is still being refined. While the attention of the fishermen is being directed to seafarming activities, training on related projects will be undertaken. Furthermore, during project implementation, fishery technicians and extension workers will regularly visit the sites to ensure the success of the projects and make the fishermen feel that they are partners to progress.

Law Enforcement

Successful enforcement and effective protection of the marine resources will require a decentralized and organized effort based in the fishing community. Community-based task forces composed of local police, government personnel, and fishermen will be given training to implement the laws in their respective areas, hence areas designated for a particular use would be zonified. Aquaculture projects, therefore, would not be disturbed by other fishing activities.

Credit

This is the most important part of FSP that would greatly enhance seafarming development. Support for small scale fishermen to engage in diversified projects including seafarming is provided. A seed fund to supplement the government Integrated Rural Financing Program will be set up.

To date, the Agricultural Credit and Policy Council was designated as manager of the credit seed fund on 15 May 1990. The Land Bank of the Philippines was designated as the conduit bank for alternative livelihood projects for fishermen on 24 November 1990 (FSP 1991). The Philippine Crop Insurance Corporation and the Guarantee Fund for Small and Medium Enterprises were tapped to provide the guarantee mechanisms for loans given by rural financing institutions and commercial banks, respectively. Negotiation with the Development Bank of the Philippines as conduit bank for aquaculture project is underway. The amount of P100 million credit seed fund has been allocated and released.

Infrastructure

Through this component, postharvest facilities such as fish landings, cold storage, and processing centers will be made available for the sector. Researches to develop and promote technology to reduce spoilage and upgrade the quality of fishery products will be undertaken.

As an offshoot, the shellfish industry will be highly benefited through the construction of depuration facilities to produce high quality product. The restriction of foreign markets to buy our shellfish due to the presence of some harmful bacteria which poses danger to human health would be reversed making shellfish as another export commodity.

CONCLUSION

Seafarming in the Philippines as an alternative livelihood for sustenance fishermen can fully substitute for fishing from the coastal waters. The development of the industry can be enhanced with the assistance of the Fisheries Sector Program. With all the components of the program supportive to mariculture, it is expected that in the near future this area would be the major contributor to fisheries production in the country.

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Ecological, Social and Economic Considerations of Seafarming and Searanching

In:F Lacanilao, RM Coloso, GF Quinitio (Eds.). Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia and Prospects for Seafarming and Searanching; 19-23 August 1991; Iloilo City, Philippines. SEAFDEC Aquaculture Department, Iloilo, Philippines. 1994. 159 p.

ECOLOGICAL IMPACTS OF SEAFARMING AND SEARANCHING[1]

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ABSTRACT

Seafarming has ecological effects such as pollution and eutrophication of adjacent areas by excess food or by feces or modification of habitats by physical structures. More subtle effects on the communities result from heavy consumption of plankton or benthos by caged or enclosed farmed organisms and consequent reduction of availability of food to adjacent natural communities. Seapens, in which monocultures are reared, develop a radically different benthos from that in adjacent areas. Seafarms can become focal points from which pathogens and parasites can be spread.

Searanching, in which stocks are enhanced by the addition of hatchery-reared recruits, has the potential to cause significant changes in the composition and stability of marine communities. Enhanced recruitment of a species will have negative effects on both its prey and its competitors but will enhance the biomass of its predators.

Enhanced recruitment of a stock of apex predators will decrease the biomass of its prey and cause changes in the composition of the community. The effects of searanching are amenable to modelling, and the likely effects of proposed searanching schemes should be examined before these are implemented.

The magnitude of the effects of searanching will depend on the degree to which the area is naturally saturated with recruits of that species and on the rate of exploitation. Poor management of the stock, resulting in under- or over-exploitation, will have highly destabilizing effects on the communities.

Seafarming or searanching can have negative effects on the gene pools of natural stocks and result in changes in life histories or in behavior.

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INTRODUCTION

The emergence of sophisticated technologies for cultivation of marine organisms, both in biological terms and in terms of the hardware available, is leading to a rapid expansion of interest in seafarming and searanching on a global basis.

Seafarming is a process whereby motile organisms are retained in enclosures or cages or, in the case of sessile organisms, cultivated on defined sectors of the seabed or on special structures created for their husbandry. Cultivation of brackishwater or marine organisms in seawater ponds or impoundments is excluded by this definition.

Searanching is a process whereby hatchery-reared stocks are introduced to marine areas, where they mingle with wild stocks of their congeners, are exposed to predators, and are, in due course, harvested by conventional fishing methods.

Such definitions become blurred in a restricted habitat or where the mobility of the organisms is limited or where predators are actively controlled. For example, shallow water species of fishes stocked into a small atoll lagoon would be bounded by oceanic depths. If predators were controlled or excluded and supplementary food provided, it would be difficult to decide whether the operation was searanching or seafarming.

The ecological effects of seafarming and searanching have received the greatest attention in relation to Atlantic salmon *(Salmo salar),* Japanese pearl oysters *(Pinctada fucata martensii),* and yellowtail *(Seriola quinqueradiata).* As seafarming and searanching expand in tropical developing countries, it is important that the possible effects, both negative and positive, on the environment and on associated biotic communities be recognized.

ECOLOGICAL EFFECTS OF SEAFARMING

The most common ecological effect of seafarming is the pollution or eutrophication of adjacent habitats by excess food or feces. The effects will be strongly mitigated by good water exchange.

In Norwegian fjords, only 10% of the sediment layer derived from salmon cages decomposes each year and the sediment layer and oxygen demand, therefore, increases for "several tens of years" before stability is reached (Aure and Stigebrandt 1990). Eutrophication effects are slight in shallow, well-flushed waters and are restricted to an increase in phytoplankton in summer months and consequent decrease in water clarity. Deep basins with poor water exchange will be adversely affected by deoxygenation of the bottom waters, as will shallow basins with poor water exchange.

In tropical seas, however, higher temperatures will accelerate rates of decomposition but exacerbate problems of eutrophication. Lam (1990) showed increased total volatile solids, total organic carbon, total nitrogen, and total phosphorus in benthic sediments in cage culture zones in Hong Kong, lower dissolved oxygen content and increased ammoniacal nitrogen in the water column. These observations suggested that water pollution problems were imminent.

Excessive sediment deposition beneath sea cages results in the release of H_2S into the water, although no fish deaths appear to have been attributed to this (Beveridge 1987).

It is not known whether or not algal blooms which affected the Norwegian coastline in recent years could be attributed to seafarming, although it has been pointed out (Rosenthal et al. 1988) that pelletized feeds contain vitamin B_{12} which is required for outbreaks of toxic red tides. There are moves in the salmon farming industry to reduce protein and phosphate contents of feeds to minimize eutrophication.

Where farms are stocked with filter feeders such as mussels, oysters, or milkfish, and the stock is dependent upon natural concentrations of phytoplankton for their feed, there will be clear limits to the density of stocks, beyond which the food supply will become depleted and growth rates retarded (Page and Ricard 1990). This will have negative affects on the farmed stocks and will also adversely affect other filter feeders in the surrounding community, with consequent effects on the community structure. In an extreme case, this could lead to severe impoverishment of an entire community.

In seapens, in which elements of the wild communities are excluded from an area, there will be a diminution of feeding grounds for benthic predators and some degree of alteration of the natural community. Likewise, heavily stocked seapens would have major impacts on the benthos, depending on whether or not the species being farmed utilized benthic food resources. If the farmed species was not a benthic feeder, elements of the benthos would enjoy protection from predators and, consequently, the seapen would function as a protected area; if it was a benthic feeder the benthos would be heavily overgrazed.

A third element in the ecological effects of seafarming is the physical alteration of the habitat by structures such as artificial reefs for sedentary organisms such as abalone, racks or stakes for bivalve cultivation, or seacages or pens. This leads to diversification of the habitat, and hence of the community, often with some adverse effects on water flow, particularly if fouling organisms accumulate on fences or meshes.

Poorly managed seafarms can serve as a source of pathogens and parasites, which can spread to natural stocks. Spread of pathogens between atolls resulting from careless transfers of spat has been reported in pearl oyster farms in French Polynesia, and the pathogens spread from *Pinctada margaritifera* to wild stocks of the same species and to *Tridacna maxima, Area ventricosa,* and *Spondylus varius* (Coeroli 1983).

Ill-considered chemical treatments, such as the use of Nuvan to control sea lice in salmon cages, have had adverse effects on adjacent populations of crustaceans. The use of wrasses in polyculture with salmon is now being advocated as a superior means of control.

For seafarming ventures which are dependent upon wild-caught fingerlings or fry, such as cage culture of grouper in Hong Kong, Malaysia, and Thailand or milkfish in many parts of Southeast Asia, recruitment to wild stocks will be reduced in proportion to the fraction of total stock of fry or fingerlings which are taken for seafarming. Taken to extreme levels, this would have a drastic impact on natural stocks and corresponding shifts in community structure. However, there is no evidence that this has ever occurred on such a scale in any stock.

ECOLOGICAL EFFECTS OF SEARANCHING

As in seafarming, the largest amount of information relates to salmon. However, their homing instincts for their natal streams make them rather a special case and there are no known instances of such precisely regulated homing instincts in tropical species.. Consequently, the situation is much simpler in comparison with salmon, where hatchery-reared stocks, or escapees from seafarms, have been found to reduce diversity of genetically-unique local stocks (Windsor and Hutchinson 1990).

The success or failure of searanching rests upon three factors: the ability of the trophic resources of the community to sustain the additional stocks, the degree to which predators can be controlled, and the degree to which fishing mortality and size at first capture can be regulated.

In the case of the trophic resources, the prime consideration is whether or not the habitat is normally saturated with recruits each spawning season. If each nursery habitat is regularly filled with naturally-spawned recruits, attempts to enhance the stock will have no effect. This would apply in the most extreme cases to recruits with specialized habit requirements such as the *Panulirus a/gnus* stocks of western Australia, in which the recruits occupy a restricted area of limestone reefs (Chittleborough 1970, Morgan et al. 1982).

In contrast, it can be argued that where larvae are widely dispersed in the oceans but will only survive if they drift to and settle onto a particular shallow water habitat, then that habitat is likely to be recruitment limited. This applies to many coral reefs where recruitment of a particular species to a particular reef appears to be a matter of chance (Doherty 1981, Munro and Williams 1985) and large variations in annual recruitment are apparently a normal occurrence (Sale 1976). Furthermore, it appears that in any aquatic community, recruitment is the major uncontrollable variable, being dependent on the coincidence of many favorable biotic factors. The degree of coincidence in turn regulates the size of the "survival window" (Bakun et al. 1982).

Addition of recruits to any system will exert additional pressure on the trophic resources with consequent reductions in the biomass of the prey and of any competitors. Likewise, the increased availability of recruits will benefit the top-level predators and could lead to progressive increases of the predators.

In any aquatic community, exploitation causes a progressive shift in the composition of communities. This shift usually involves both a relative and an absolute decrease in predatory species and increases in relative abundances of species at the low end of the food chain (Munro and Smith l985). Consequently, exploitation will lead to a greater degree of unutilized trophic resources, which will be recycled to detritus. For example, in a multispecies tropical fishery, the larger and more desirable predatory species such as snappers or groupers, are often targeted by a wider variety of fishing gears, their catchability is greater than that of a smaller species and the ratios of their natural mortality and growth coefficients (M/K) are lower; they are less resilient to heavy fishing than species such as penaeid shrimp with very high M/K ratios.

Thus, in a heavily exploited aquatic community the entire trophic pyramid is flattened. Stocking an apex predator might be ineffective if their prey species have been drastically depleted by fishing. It might be necessary to stock the prey species as well.

Two models are available for anticipating the effects of searanching. Polovina (1990) has presented modifications of both yield per recruit and surplus production models, which allow the numbers of hatchery-reared recruits to be factored into the calculations. By this means, the additional harvests that might be expected as a result of a searanching program can be calculated. However, a major assumption is that natural mortality rates will continue unchanged. Both of these models also yield estimates of the biomass which would be attained by the ranched stock. The biomass estimates, in turn, will permit the application of the Ecopath program (Polovina and Ow 1983, Polovina 1984), which, in its latest form, Ecopath II (Christensen and Pauly 1991), will enable the investigators to estimate the effect of the increased biomass of the target species on the rest of the community.

An additional possibility which has been done on a small scale in Japan with red sea bream *(Pagrus major)* is supplementary feeding of searanched fishes (Cowan 1981). When this is combined with luring fishes to feeding stations or to harvest sites with acoustic signals, the boundaries between searanching and seafarming become very blurred. However, there is no theoretical impediment to factoring the supplementary feeds into a trophic resource model.

INTRODUCTIONS OF EXOTIC SPECIES

One of the most potentially serious ecological consequences of Seafarming or searanching results from the introduction of alien species. Farmed species will inevitably escape and mass releases of an exotic species selected for searanching could have extreme effects on the natural communities. For example, coho salmon *(Oncorhynchus kisutch)* have been introduced to the northwest Atlantic. They were thought to be ecologically separated from Atlantic salmon but now there are concerns that they favor the same gravel beds for spawning. This results in the redds of the Atlantic salmon being disrupted and could result in the replacement of the more valuable Atlantic species by the less favored coho (Windsor and Hutchinson 1990).

CONCLUSION

An important corollary to all of the foregoing is that there is little point in attempting searanching in an unmanaged open-access fishery. All benefits would be marginalized by fishermen targeting the new stock.

Likewise, even in a well regulated system the degree to which the natural stocks are supplemented by hatchery-reared recruits should ideally be related to the strength of natural recruitment, with supplementary stocking being unnecessary on those occasions when an area is naturally saturated with new recruits. A recruitment monitoring program is, therefore, a necessary adjunct to a searanching program, both to maximize production and to avoid calamitous depletion of the trophic resources and consequent collapse of the target fish stock.

In the context of seafarming, careful planning with regard to siting of seafarms, optimizing inputs of feed, and minimizing inputs of chemical treatments will do much to mitigate the effects on water quality and on the ecology of the seabed.

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ECONOMIC AND SOCIAL CONSIDERATIONS IN SEAFARMING AND SEARANCHING

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ABSTRACT

Sustainable development of seafarming and searanching calls for careful planning. Investments in seafarming must take into account environmental, biotechnological, and socioeconomic considerations. Investment planning must be carefully examined as well as the physical design of production systems such that its negative impact is minimized and the positive impact is accentuated.

Supply from the wild may not be expected to grow much higher than present levels. Many of the major commercially valuable fisheries are now overfished at or close to their respective minimum sustainable yield levels. Seafarming can attract some of the fishermen out of overcrowded fisheries.

Production cost of seafarming produce is a major concern which has to be examined closely if these are to compete with and gradually supplant the supply of fish from the wild. Feed is one of the main inhibiting factors, hence, efficient consideration calls for constantly improving feed conversion and productivity per unit input.

Existing government policies are not clear nor conducive to seafarming in terms of use rights of coastal waters. To attract potential investors into seafarming, governments are encouraged to review existing policies governing use rights to coastal waters, package the necessary technology consistent with the country's wage and price structure, and develop investment profile for seafarming opportunities using conservative criteria.

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INTRODUCTION

The seafood we eat today comes from the wild and aquaculture. The introduction of fish trawling in the 1950s and the use of both active and passive gears have consistently decimated the standing stocks of aquatic resources.

Although marine fish landings can be increased through better management and use of presently underexploited stocks, seafarming is one alternative aquaculture technique for increasing fish supply.

This paper examines the economic and social aspects of seafarming. It sets out and delineates the economics of seafarming to provide the necessary information/data to support its orderly and systematic development and expansion and to attract investors and financial institutions into seafarming.

A broad overview of the techno-socioeconomics of seafarming at the aggregate level, especially the structure of the industry, production, and markets for products are presented.

Seafarming: Tomorrow's Fish Supply

Except for the years 1983/1984 and 1985/1986 when the rate of increase in total fish catch grew by 8.3 and 7.4%, respectively, the world landings of fish has grown very slowly at an annual average of 3.4% due to indiscriminate fishing and fisheries habitat degradation and destruction.

Production from aquaculture, of which seafarming is a recent but increasingly viable source of supply, is steadily increasing. Today, production from aquaculture accounts for at least 15%.

Overexploitation of fisheries resources in many countries, especially developing ones, is due to extreme poverty, unenforceable fisheries management measures, lack of alternative possibilities, lack of better choice in the technique of production for capture and culture fisheries until recently.

The recent improvements in aquaculture technology (seed production, nutrition, production methods), made seafarming a natural and logical extension of capture fishing.

ECONOMIC AND SOCIAL CONSIDERATIONS

Economic and social considerations for seafarming will be examined from two broad perspectives, namely (1) resource-based system means that seafarming methods, practices, and techniques emphasize the use of resources most abundant in the production site more than the reliance on advanced or high technology and (2) technology-based system means the application of advanced technology and science to the production process.

Site and Scale Production

The seafarming system to be developed has direct relationship to the choice of sites and size of operation.

Production site has been identified by various studies as one of the main factors responsible for the failures of aquaculture. Recently, the Committee on Fisheries at its 17th Session has identified, among others, site and social environment as partly responsible for aquaculture's poor performance.

Moreover, production site has a direct relationship to the scale of production (large, medium, or small-scale). The ease or difficulty with site acquisition will vary according to the proposed scale or size of the farm.

Centralization of seafarming set-up (broodstock, hatchery, nursery, transition, and grow-out systems) would facilitate farm management and operation under normal conditions. Production (e.g., labor efficiency) and cost efficiency (duplication of certain facilities) are more easily attainable in one location than in scattered sites.

It is also technically and economically worthwhile to separate the different production sub-systems into more than one site, e.g., disease outbreak in one site will not affect other sites.

Production Intensity

The economics (i.e., costs and returns) of the level of production system intensity (extensive, semi-intensive, or intensive) influence the profitability of seafarming. For shrimp aquaculture in the Asian region, costs of production per kilogram decline more rapidly with each increase in productivity gains for extensive and semi-intensive systems than for intensive culture. Fixed costs (capital investments) of the intensive system is very high and even with improved productivity, the unit costs decline insignificantly.

On the other hand, the cost of production per unit of output is lower for intensive than for extensive operations. As in the case of milkfish aquaculture in Indonesia and the Philippines. Yield per hectare under intensive operation can be increased three times that of extensive culture by doubling the cost of production. The resulting profit is much higher given the price of milkfish, prevailing in the two countries.

Similarly, production cost per ton of common carp in an intensive system is about 40% less than in an extensive system in Israel. Production cost is not only influenced by the intensity of production but also the technology and inputs to be employed.

The natural, spatial, topographical, hydrobiological, and hydrographical features of each potential seafarming site govern the ease of difficulty with which the site can be developed.

The choice of production intensity level also depends on the relative costs of each of the natural resources or inputs available in the area.

If coastal land and sea front is abundant and, thus, land cost is low, the extensive method would be appropriate (as in some parts of Latin America for shrimp culture). On the other hand, if coastal land or long-term accessibility to the sea front (seafarming) is scarce or limited, thus, making beach front land prices and leasehold fees relatively high as in Japan, Republic of Korea, Hong Kong, Taiwan, and Singapore, the intensive method is resorted to.

From the stand point of the national economy and ecology, whatever system intensity is planned, the Seafarming production system developed should be designed with the environment in mind. In the long-run, this approach is socioeconomically sound.

Target Species

The target species to be cultured is another important economic consideration in Seafarming. In general, target species can be classified into: 1) high value, 2) low value, 3) high value, low volume, and 4) low value, high volume.

Depending on its profitability the investor can select the high value species or be encouraged to produce for the low-income markets with suitable government incentives and policy.

At present, Asian aquaculture accounts for more than three-fourths of total world production at 10 million tons. Of this, about 42% and 32% are from fish and seaweeds, respectively. Another 24% are shellfish or crustaceans. Shrimps constitute only 2.5%. Because seaweeds are mostly cultivated in shallow seas and are relatively low-valued, this pattern and trend in production distribution by major species groups show that development of fish and shellfish seafarming could still be developed.

Of the 40 species of fish and 20 species of shellfish cultured in Asia, **a** large percentage (except some shrimp species) is of relatively low value. Because of the declining catch of marine species, Seafarming of these high value species can fill the supply shortfall from the wild.

Capital Investment Fixed Costs

Availability of capital could directly influence the farm design and layout, size of operation, product or species-mix, and technology to be employed.

The cost of acquiring or leasing the long-term use rights to the sea front or coastal land should also be considered. To safeguard and protect the capital, it is important that such use rights be secured on a long term basis to recover the capital. As much as the coastal zone, is in the public domain, a contract can be drawn up with the government to maintain tenurial or "property" rights.

Once the site is selected, the cost of capital development of production facilities has to be considered. Such capital cost can be partly offset by valuable products from the site like wood, fruits, roof thatch, and other products of aquatic or animal origin. Remodelling the seashore and adjacent land involves sea floor or mud flat modification or preparation for seeding, installation of stakes, longlines and cement/hollow blocks for spat collection, pen and cage, pond, water supply and drainage canal, dikeberm and water gate construction, hatchery building, office (including a modest laboratory), and storage facilities. Other capital items include water pumps and jet sprayers, boats, generator set, and a miscellany of water quality test kits and chemicals.

Production Costs

Production costs are an integral component and consideration of seafarming. The main cost components of aquaculture (mostly variable costs) are: (1) seeds - 20-50%, (2) feeds/fertilizers - 30-70%, (3) labor -15-20%, (4) others - 5-10%.

National Land-use Planning and Policy

Before implementing a seafarming project, national policy (including regulations in coastal resource use), plan, and assistance should be studied and reviewed. Such information can reduce site exploratory costs.

To encourage the orderly development of aquaculture, especially sites for seafarming, government should develop criteria (technical and non-technical) and zoning laws and regulations governing the use of virgin areas for aquaculture. Furthermore, many government bodies have direct or indirect jurisdiction over the use of land and water for fish farming contributing much confusion as to who has the final authority in granting a permit to start a fish farm.

As 80-93% of the world's agricultural land is already in use, the scope for land-based aquaculture production systems is rather limited. Attention can be directed and focused on the sea as possible production sites. However, greater attention should be given to proper planning and implementation.

Present Land Use Pattern. It is important to know whether or not the potential site for seafarming is in an area where aquaculture is earmarked for fish culture, or situated next to an industrial, residential, or agricultural zone.

If the proposed site is within the vicinity of a predominantly agricultural area or adjacent to an industrial zone, agricultural runoffs (both good and bad) would be a concern. The extent of use of chemical fertilizers, pesticides, and industrial effluent will affect water quality.

Tenurial System. Land and water body tenurial arrangements vary from country to country. Depending on the land (reform) laws or laws governing the use of the sea or water bodies in each country, tenurial arrangements can range from outright purchase and ownership to lease or rental arrangement.

Except for water bodies (rivers, lakes and seas) and land adjacent to such water bodies which remain public domain, private citizens are and can own land in many countries. In such cases, land acquisition can be negotiated with the individual owners. Otherwise, land acquisition is arranged with the government.

Property Rights and Security. The foremost consideration under property rights and security are risks and uncertainty. Exposure to risks of a site for seafarming can be minimized if certain precautions are instituted. These precautionary measures cost money to carry out.

Pilferage is of prime consideration because without the assurance of getting an economic return, the farm would fail. The costs of surveillance (guards, and other electronic deterrents) show up in production costs. They are in turn translated into higher selling prices.

Goodwill with the surrounding community or can and must be fostered. Recruiting and employing the local labor force wherever possible would ensure goodwill and cooperation and thus, alleviate part of the social problems.

Insurance Coverage. Is the prospective site for seafarming insurable? Some insurance companies would not sell a policy because of the inaccessibility of the farm. An insurance policy is a wise investment to protect against future loss arising from theft and pilferage, vandalism, or storm damage and other natural causes The location of the farm plays a role in determining whether a policy can be obtained or not.

Sources of Financing Credit

The source of capital to finance acquisition and development of the farm site has direct relationship to site selection. Large investors usually have little difficulty in financing or obtaining credit while small farmers face real problems in obtaining credit.

To encourage accelerated Seafarming development, many governments are known to provide different types of assistance. These are: 1) small coastal land grant of virgin areas determined as suited for seafarming, 2) low interest credit financing either for capital development (site construction) or operating costs (input purchase), and 3) government coastal land leasehold system with simple and renewable terms such as Philippine Ordinary Fishpond Permit and Fishpond Lease Agreement.

Commercial lending institutions have also shown interest in financing aquaculture investments.

Accessibility to Input and Output Markets

If the production site is inaccessible by the existing road network, additional capital costs would have to be incurred to build an access road linking the existing road system.

Fair to good logistics and low cost means of transportation linking production centers to consumption centers can make or break a new aquaculture facility. The economics of transporting needed inputs to the production site and outputs to the markets (e.g. cold storage facility and onward shipment as exports) need to be determined beforehand.

Labor Supply and Costs

In many developing countries, such as Indonesia, coastal land and shoreline suitable for Seafarming may be found in sparsely populated areas. Supply of a reliable, low-cost skilled labor becomes critical because labor cost accounts for about 15-20% of the total costs of production for most aquaculture system. Thus, many aquaculture sites are found near urban areas which are the population and consumption centers. While recruitment of unskilled labor can be done locally, recruitment of semi-skilled and skilled labor may have to be done further afield. For some countries, it may be necessary to import such labor.

Employment

Aquaculture is regarded as one national economic sector which can absorb the labor entering the labor market annually. Governments are interested in allocating land along the coast or sea front for aquaculture in the rural areas and are actively pushing its development and expansion.

Shang and Rabanal (1976) also reported that intensive milkfish culture in Indonesia and the Philippines creates more job opportunities in the rural areas because of greater need for fertilization and frequent stocking and harvesting.

RISK OF URBAN ENCROACHMENT

Site selection for seafarming also has to take into account the risk of urban encroachment in the short and long-term. This is a very real problem in many countries because as the population multiplies rapidly, valuable agricultural lands including fish farms are lost to housing or industrial development.

EXTERNALITY

A site for seafarming should also be away from all possible sources of problems which management has little or no control of such as pollution (e.g. domestic sewage, agricultural run-off, and industrial wastes), theft, etc.

The potential seafarming investor should know how other resource users and producers and consumers in the vicinity and adjacent to the site will influence his production and costs. Likewise, he should recognize how his seafarming activities would affect his neighbors. This is important in today's legal works given the opportunity for legal resource for infractions of rights, loss, etc.

DISCUSSION AND CONCLUSION

In Asia where aquaculture dates back more than 2,500 years and land and population account for about 20 and 60%, respectively, of the total world land area and population, sites available and suitable for aquaculture are scarce, in particular on land. Water bodies like the sea are increasingly being looked into as possible new sites.

The success of seafarming depends largely on site-specific factors. While the biotechnical factors describe the production possibilities or production frontier, economic and market forces shape the profitability of seafarming.

By pointing out as well as bringing together all possible considerations from the economic and social perspectives, the technical evaluation of seafarming can be broadened and enriched.

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